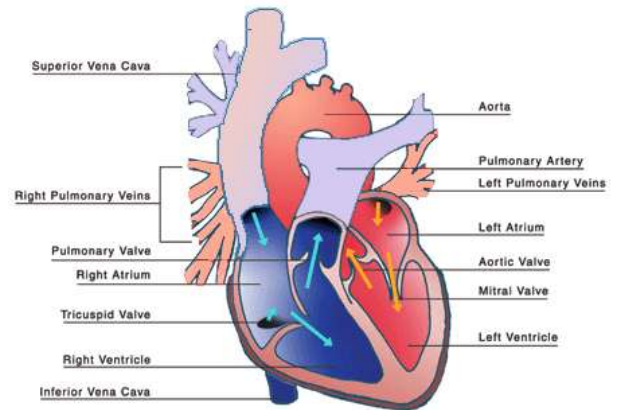


Heart's Conduction System and the ECG

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.



Measuring 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 CO_2 waste is released and O_2 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 O_2 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.

The Effect of Changing Body Posture on Blood Pressure

Gravity is a constant force that influences nearly every aspect of biological activity, to some extent. The gravitational force on organisms follows physical laws that are well-known; thus, the gravity can have predictable effects. There are gravitational forces acting on physiological systems such as the cardiovascular and circulatory systems. Any fluid columns, like blood vessels, are subjected to large pressure gradients when subjected to sudden changes in body posture, especially in humans which are designed for upright posture. There are physiological adaptations in the human cardiovascular system designed to counteract the effects of gravity on the circulatory system under postural changes such as when in a standing, sitting, or lying down (**supine**) position. Some of the things occur in the body in response to changes in posture are heart rate (number of heart beats per minute) and **blood pressure** (pressure of blood against arterial vessel walls).

When you lie down in the supine position, your heart is at the same gravitational level as the blood vessels in our head and limbs. Therefore, when lying down your blood pressure is similar along your entire body and blood return to the heart is less influenced by the pull of gravity. When you stand for a long period of time without moving, or when you have lain down for a long time and stand up suddenly, you might experience a feeling of faintness or dizziness that



passes quickly. This slight dizziness is due to the effects of gravity on the cardiovascular system. This sudden posture change from a supine to an upright posture creates a strong vertical gradient of gravitational pull on the fluid (blood) in our circulatory column. The heart is now below the head and neck, and the heart is approximately 2-4 ft above the legs. Blood pressure decreases briefly in the head and neck while pressure increases in the legs. Furthermore, the increased blood pressure in our lower limbs causes blood to pool in our venous system because the vessels are elastic and stretchy, unlike the rigid-walled arterial vessels. The venous system stores about 80% of your total blood volume while the arterial system stores about 10% at any one time. Thus, the venous system is a blood reservoir.

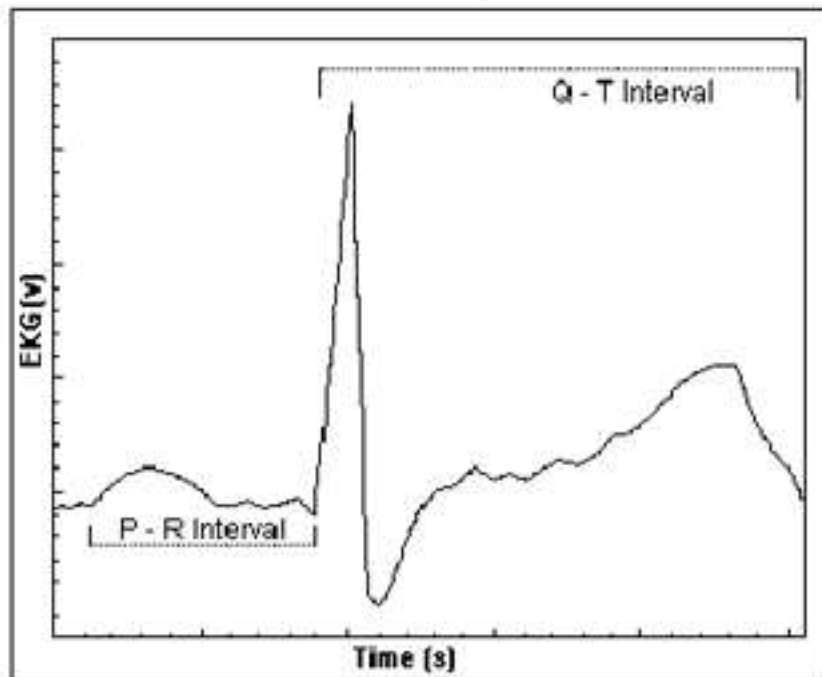
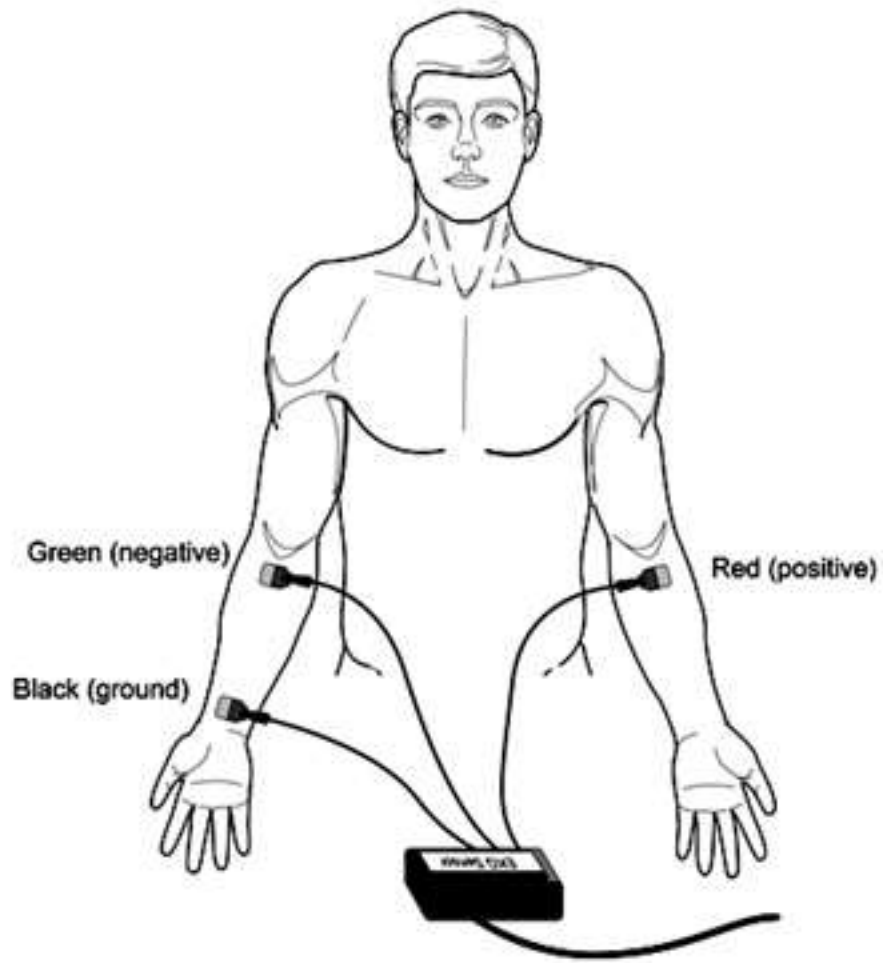
There are several things that occur in your body when you change from a supine to a standing position quickly: (1) there is a **decrease in venous return of blood to the heart**. Blood pools in the elastic-walled venous vessels due to the sudden increased gravitational pull on blood within your lower limbs; **(2) there is a decrease in cardiac blood volume (end diastolic volume)** due to the decreased venous return; and **(3) there is a decrease in arterial blood volume and blood pressure within your head and neck**. These changes are sometimes accompanied by feelings of dizziness or light-headedness, and might even lead to fainting (**syncope**).

When you change quickly from a supine to an upright posture **there are several things that your body will do immediately to counteract the change in blood pressure and pooling of blood in the veins. (1) Your heart rate increases and pumps a greater volume of blood**. This will increase **blood pressure (BP)** so that you avoid fainting. **(2) The valves in your veins maintain a one-way flow of blood to the heart which aids venous return of blood to the heart.** **(3) Your skeletal muscles contract and help compress the veins providing resistance to pooling of blood**. These muscle twitches act much like a flight suit of jet pilots which squeeze the body and provide resistance to the elastic-walled veins. **(4) The nervous system elicits several compensatory and autonomic sympathetic responses to restore normal blood volume and pressure**. Your medulla oblongata has two autonomic centers: the cardiac and vasomotor center. The cardiac center responds by increasing sympathetic stimulation, by epinephrine/norepinephrine, of increased heart rate by increasing cardiac pacemaker cell depolarization rates. The medulla also stimulates vasoconstriction of smooth muscle within arterioles, especially those leading to the brain, to increase blood pressure against the force of gravity.

Part 1: The Electrocardiogram

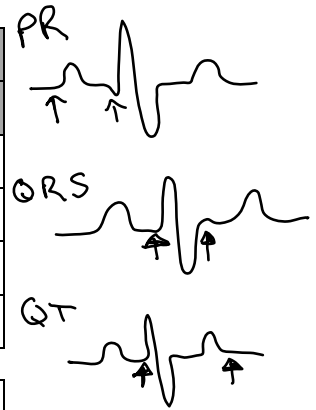
Today in Lab we will monitor the electrical activity of the heart with electrodes and Vernier equipment to produce a graphical representation of the events i.e. an electrocardiogram (ECG or EKG).

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.



DATA

Interval	At rest	After exercise
P - R		
QRS		
Q - T		
Full Heart Cycle		
Heart Rate beats/min		



Standard Resting Electrocardiogram Interval Times	
P - R interval	0.12 to 0.20 s
QRS interval	less than 0.10 s
Q - T interval	0.30 to 0.40 s

Part 2: Measuring Blood Pressure Responses to Changes in Body Posture

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.

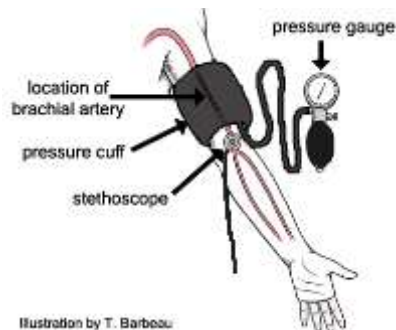


Illustration by T. Barbeau

Pressure gauge of a sphygmomanometer



Image by T. Barbeau

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.

Exercise 1: Measuring Heart Rate

Use two fingers (index and second finger) and lightly press them against the wrist below the thumb. Do not press too hard or you will block blood flow in the **radial artery**. Once you detect the pulse, record the number of beats in 15 seconds. Then multiply that number by 4 to get the beats per minute. The pulse can also be palpated in the **carotid artery** on the side of your neck.

Exercise 2: Procedure for Measuring Blood Pressure:

1. Work with your lab partner and have them roll up their sleeve exposing their arm. Place the cuff of the BP cuff snugly around the biceps of the arm (not too tight!). Keep the chords of the BP cuff on the upper arm surface pointing towards the elbow. The arm should be resting comfortably on the lab table, palm up. Have the person hold the pulse monitor in the hand of the arm not having the BP cuff. Try and record resting heart rate at the same time as you perform the following steps.
2. Attach the BP cuff with the Velcro strap and keep the gauge where you can read it easily.
3. Use a stethoscope placed underneath the cuff to listen through the ear pieces for the sound of blood in the arteries of your partner. You will not hear anything until you perform step 5.
4. Close the valve on the BP cuff by turning it clockwise. Pump air into the cuff by squeezing the rubber bulb until the pressure reading reaches about 150 – 180 mmHg. **Please listen to your partner** and stop if this hurts. The pressure will collapse the brachial artery, so do not keep this pressure on the arm for more than 30 seconds!
5. Open the bulb **SLOWLY**. The needle on the pressure gauge should fall at a rate of 2-3 mmHg per second. You need to listen carefully as you observe pressure falling.
6. At the **FIRST SOUND** in the stethoscope, record the pressure. This is the systolic BP or the pressure at which the heart's ventricular contraction can again force blood through the brachial artery in the upper arm. You might also see the dial on the pressure gauge begin to jump with each heart beat.
7. You will hear the sound of the blood pressure increase, and then fade. When the **SOUNDS STOP**, record the diastolic pressure.
8. Trade places with your partner and repeat the process.

Locating and Detecting the Radial Pulse



Exercise 3: Comparing Heart Rate and Blood Pressure Between Supine and Standing Postures.

Now you will examine blood pressure and heart rate while in a supine position followed by a sudden change to an upright posture. This will require your use of both the pulse monitor to record heart rate and the blood pressure cuff to record systolic and diastolic blood pressure.

1. Have your partner rest comfortably with sleeves rolled up on their arm. Place the BP cuff on their arm and secure gently with the Velcro strap. Place the stethoscope in position over the arm, under the cuff. Have a finger placed on the pulse monitor using the hand of the arm not wearing the BP cuff. Let the person lie quietly for 5 minutes without moving or raising the limbs.
2. After 5 minutes of resting, record the supine heart rate.

Supine Heart rate = _____ bpm

3. Now pump up the cuff (making sure the valve is closed) to about 150 – 200 mmHg and then slowly release the pressure. Record the Systolic BP and Diastolic BP.

Supine Systolic BP = _____ mmHg

Supine Diastolic BP = _____ mmHg

4. Keep the blood pressure cuff (with pressure released), stethoscope, and pulse monitor in position and let the person rest in the supine position for 5 more minutes.
5. You are now going to have the person get up quickly to an upright posture (standing). Please watch your partner for any sign of fainting! Within 10 seconds of standing you must repeat the above procedure and record the following:

Standing Heart Rate = _____ bpm

Standing Systolic BP = _____ mmHg

Standing Diastolic BP = _____ mmHg

6. Switch places with your partner and repeat the supine and standing measurements of heart rate and blood pressure. When you are finished put BP cuffs, stethoscopes, and pulse monitors away at front desk. Compile class data on the table and record them in Tables 1 and 2.

Analyses:

Your instructor might have a computer available with an **Excel spreadsheet open for you to enter your data** there also. Either by calculator or the Excel spreadsheet, calculate average class heart rate while lying down and immediately after standing up suddenly. Calculate the average blood pressure (systolic BP and diastolic BP) while lying down and immediately after standing.

Table 1. Class Summary Data: Heart Rate With Posture Change

Heart Rate After Fast Postural Change		
Student	Supine Heart Rate (bpm)	Standing Heart Rate (bpm)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		
13.		
14.		
15.		
16.		
17.		
18.		
19.		
20.		
21.		
22.		
23.		
24.		
AVG BPM		

Table 2. Class Summary: Blood Pressure With Posture Change

Table 2: Class Blood Pressure	Blood Pressure While in Supine Position (Lying Down)		Blood Pressure After Fast Postural Change (Standing Up <10 sec)	
	Student	Supine SBP	Supine DBP	Standing SBP
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.				
19.				
20.				
21.				
22.				
23.				
24.				
AVG BP				

Questions: Cardiovascular Lab

Name _____

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?

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

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

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

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.

Part 2: Blood Pressure

6. What are some reasons for hypertension? _____
_____.

7. What are some dangers associated with chronic hypertension? _____
_____.

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

9. What is syncope? _____
_____.

10. What do you think will happen to heart rate after you stand up after lying down for 5 minutes? Give a biological explanation, based on what you know about cardiovascular physiology.

11. What do you think will happen to your systolic and diastolic blood pressure after you stand up after lying down for 5 minutes? Give a biological explanation, based on what you know about cardiovascular physiology.

12. Why would a jet pilot or astronaut wear a tight suit when embarking on a flight?

