

Physiology of the Circulatory System

modified from <http://www.ekcsk12.org/science/aplabreview/aplab10.htm>

Introduction

The circulatory system functions to deliver oxygen and nutrients to tissues for growth and metabolism, and to remove metabolic wastes. The heart pumps blood through a circuit that includes arteries, arterioles, capillaries, venules, and veins. One important circuit is the pulmonary circuit, where there is an exchange of gases within the alveoli of the lung. The right side of the human heart receives deoxygenated blood from body tissues and pumps it to the lungs. The left side of the heart receives oxygenated blood from the lungs and pumps it to the tissues. With increased exercise, several changes occur within the circulatory system, thus increasing the delivery of oxygen to actively respiring muscles cells. These changes include increased heart rate, increased blood flow to muscular tissue, decreased blood flow to non muscular tissue, increased arterial pressure, increased body temperature and increased breathing rate.

Blood Pressure

An important measurable aspect of the circulatory system is blood pressure. When the ventricles of the heart contract, pressure is increased throughout all the arteries. Arterial blood pressure is directly dependent on the amount of blood pumped by the heart per minute and the resistance to blood flow through the arterioles. The arterial blood pressure is determined using a device known as a **sphygmomanometer**. This device consists of an inflatable cuff connected by rubber hoses to a hand pump and to a pressure gauge graduated in millimeters of mercury. The cuff is wrapped around the upper arm and inflated to a pressure that will shut off the brachial artery. The examiner listens for the sounds of blood flow in the brachial artery by placing the bell of a stethoscope in the inside of the elbow below the biceps.

At rest, the blood normally goes through the arteries so that the blood in the central part of the artery moves faster than the blood in the peripheral part. Under these conditions, the artery is silent when one listens. When the sphygmomanometer cuff is inflated to a pressure above the systolic pressure, the flow of blood is stopped and the artery is silent again. As the pressure in the cuff gradually drops to levels between the systolic and diastolic pressures of the artery, the blood is pushed through the compressed walls of the artery in a turbulent flow. Under these conditions, the blood is mixed, and the turbulence sets up vibrations in the artery that are heard as sounds in the stethoscope. These sounds are known as the heart sounds or sounds of **Korotkoff**. The sounds are divided into five phases based on the loudness and quality of the sounds.

- Phase 1.** A loud, clear tapping sound that increases in intensity as the cuff is deflated.
- Phase 2.** A succession of murmurs can be heard. Sometimes the sounds seem to disappear during this time which may be a result of inflating or deflating the cuff too slowly.
- Phase 3.** A loud, thumping sound, similar to that in **Phase 1** but less clear, replaces the murmurs.
- Phase 4.** A muffled sound abruptly replaces the thumping sounds of **Phase 3**.
- Phase 5.** All sounds disappear.

The cuff pressure at which the first sound is heard (**beginning of Phase 1**) is taken as the **systolic pressure**. The cuff pressure with the muffled sound (**Phase 4**) disappears (**beginning of Phase 5**). is taken as the measurement of the **diastolic pressure**. A normal blood pressure measurement for a given individual depends on a person's age, sex, heredity, and environment. When these factors are taken into account, blood pressure measurements that are chronically elevated may indicate a state deleterious to the health of the person. This condition is called **hypertension** and is a major contributing factor in heart disease and stroke.



Table 10.1: Normal Blood Pressure for Men and Women at Different Ages

Age in Years	Systolic Pressure		Diastolic Pressure	
	Men	Women	Men	Women
10	103	103	69	70
11	104	104	70	71
12	106	106	71	72
13	108	108	72	73
14	110	110	73	74
15	112	112	75	76
16	118	116	73	72
17	121	116	74	72
18	120	116	74	72
19	122	115	75	71
20-24	123	116	76	72
25-29	125	117	78	74
30-34	126	120	79	75
35-39	127	124	80	78
40-44	129	127	81	80
45-49	130	131	82	82
50-54	135	137	83	84
55-59	138	139	84	84
60-64	142	144	85	85
65-69	143	154	83	85
70-74	145	159	82	85

Exercise 10A: Measuring Blood Pressure

Note: This lab is ONLY for experimental, and not diagnostic, purposes.

A sphygmomanometer (blood pressure cuff) is used to measure blood pressure. The cuff, designed to fit around the upper arm, can be expanded by pumping a rubber bulb connected to the cuff. The pressure gauge, scaled in millimeters, indicates the pressure inside the cuff. A stethoscope is used to listen to the individual's pulse.

Procedure

1. Work in pairs.
2. Attach the cuff of the sphygmomanometer snugly around the upper arm.
3. Place the stethoscope directly below the cuff in the bend of the elbow joint.
4. Close the valve of the bulb by turning it clockwise. Pump air into the cuff until the pressure gauge goes past 200 mm Hg.
5. Turn the valve of the bulb counterclockwise and slowly release the air from the cuff. Listen for pulse.
6. When you first hear the heart sounds, note the pressure on the gauge. **This is the systolic pressure.**
7. Continue to slowly release air and listen until the clear thumping sound of the pulse becomes strong and then fades. When you last hear the full heart beat, note the pressure. **This is the diastolic pressure.**
8. Repeat the measurement two more times and determine the average systolic and diastolic pressure, then record these values on the data sheet .
9. Trade places with your partner. Record average systolic and diastolic pressure on the blood pressure data sheet.

Exercise 10B: A Test of Fitness

The point scores on the following tests provide an evaluation of fitness based not only on cardiac muscular development but also on the ability of the cardiovascular system to respond to sudden changes in demand. **Caution: Make sure that you do not attempt this exercise if strenuous activity will aggravate a health problem.** Work in pairs. Determine the fitness level for one member of the pair (Tests 1 to 5 below) and then repeat the process for the other member of the pair.

Procedure

1. The subject should recline on a laboratory bench for at least 5 minutes. At the end of this time, measure the systolic and diastolic pressure and record these values below.
reclining systolic pressure _____ mm Hg
reclining diastolic pressure _____ mm Hg
2. Remain reclining for two minutes, then stand and IMMEDIATELY repeat measurements on the same subject (arms down). Record these values below.
standing systolic pressure _____ mm Hg
standing diastolic pressure _____ mm Hg
3. Determine the change in systolic pressure from reclining to standing by subtracting the standard measurement from the reclining measurement. Assign fitness points based on Table 10.2 and record the fitness data sheet.

Table 10.2: Changes in Systolic Pressure from Reclining to Standing

Change (mm Hg)	Fitness Points
rise of 8 or more	3
rise of 2-7	2
no rise	1
fall of 2-5	0
fall of 6 or more	-1

Cardiac Rate and Physical Fitness

During physical exertion, the cardiac rate (beats per minute) increases. This increase can be measured as an increase in pulse rate. Although the maximum cardiac rate is usually the same in people of the same age group, those who are physically fit have a higher stroke volume (millimeters per beat) than more sedentary individuals. A person who is in poor physical condition, therefore, reaches their maximum cardiac rate at a lower work level than a person with of comparable age who is in better shape. Maximum cardiac rates are listed in Table 10.3. Individuals who are in good physical condition can deliver more oxygen to their muscles before reaching maximum cardiac rate than can those in poor condition.

Table 10.3: Maximum-Pulse Rate

Age (years)	Maximum Pulse Rate (beats/min)
20-29	190
30-39	160
40-49	150
50-59	140
60 and above	130

Test 2: Standing Pulse Rate

Procedure

1. The subject should stand at ease for 2 minutes after Test 1.
2. After the two minutes, determine your partner's pulse.
3. Count the number of beats for 30 seconds and multiply by 2. The pulse rate is the number of beats per minute. Record this on the fitness data sheet. Assign fitness points based on Table 10.4 and record them on the data sheet.

Table 10.4: Pulse Rate and Fitness Points

Pulse Rate (beats/min)	Fitness Points
60-70	3
71-80	3
81-90	2
91-100	1
101-110	1
111-120	0
121-130	0
131-140	-1

Test 3: Reclining Pulse Rate

Procedure

1. The subject should recline for 5 minutes on the laboratory bench.
2. The other partner will determine the subject's resting pulse.
3. Count the number of beats for 30 seconds and multiply by 2. (Note: the subject should remain reclining for the next test!) Record it on the Data Sheet. Assign fitness points based on Table 10.5 and record them on the fitness data sheet.

Table 10.5: Reclining Pulse Rate

Pulse Rate (beats/min)	Fitness Points
50-60	3
61-70	3
71-80	2
81-90	1
91-100	0
101-110	-1

Test 4: Baroreceptor Reflex (Pulse Rate Increase from Reclining to Standing)

Procedure

1. The reclining subject should now stand up.
2. Immediately take the subject's pulse. Record this value below. The observed increase in pulse rate is initiated by baroreceptors (pressure receptors) in the carotid artery and in the aortic arch. When the baroreceptors detect a drop in blood pressure they signal the medulla of the brain to increase the heart beat, and consequently the pulse rate.

Pulse immediately upon standing = _____ beats per minute

3. Subtract the reclining pulse rate (recorded in Test 3) from the pulse rate immediately upon standing (recorded in Test 4) to determine the pulse rate increase upon standing. Assign fitness points based on Table 10.6 and record on the fitness data sheet.

Table 10.6: Pulse Increase from Reclining to Standing

Reclining Pulse (beats/min)	Pulse Rate Increase on Standing (# beats)				
	0-10	11-18	19-26	27-34	35-43
	Fitness Points				
50-60	3	3	2	1	0
61-70	3	2	1	0	-1
71-80	3	2	0	-1	-2
81-90	2	1	-1	-2	-3
91-100	1	0	-2	-3	-3
101-110	0	-1	-3	-3	-3

Test 5: Step Test- Endurance

Procedure

1. Place your right foot on an 18-inch high stool. Raise your body so that your left foot comes to rest by your right foot. Return your left foot to the original position. Repeat these exercise five times, allowing three seconds for each step up. (An alternative procedure could be to quickly climb our stairs.)
2. Immediately after the completion of the exercise, measure the pulse for 15 seconds and record below; measure again for 15 seconds and record; continue taking the pulse and record at 60, 90, and 120 seconds.

Number of beats in the 0-to 15 second interval ____ X 4 = ____ beats per minute
 Number of beats in the 16-to 30 second interval ____ X 4 = ____ beats per minute
 Number of beats in the 31-to 60 second interval ____ X 4 = ____ beats per minute
 Number of beats in the 61-to 90 second interval ____ X 4 = ____ beats per minute
 Number of beats in the 91-to 120 second interval ____ X 4 = ____ beats per minute

3. Observe the time that it takes for the pulse rate to return to approximately the level as recorded in Test 2. Assign fitness points based on Table 10.7 and record them on the fitness data sheet.

Table 10.7: Time Required for Return of Pulse Rate to Standing Level after Exercise

Time (seconds)	Fitness Points
0-30	4
31-60	3
61-90	2
91-120	1
121+	1
1-10 beats above standing pulse rate	0
11-30 beats above standing pulse rate	-1

4. Subtract your normal standing pulse rate (recorded in Test 2) from your pulse rate immediately after exercise (the 0-to 15-second interval) to obtain pulse rate increase. Record this on the Blood Pressure Data Sheet (below). Assign fitness points based on Table 10.8 and record them on the fitness data sheet.

Standing Pulse (beats/min)	Pulse Rate Increase Immediately after Exercise (#beats)				
	0-10	11-20	21-30	31-40	41+
	Fitness Points				
60-70	3	3	2	1	0
71-80	3	2	1	0	-1
81-90	3	2	1	-1	-2
91-100	2	1	0	-2	-3
101-110	1	0	-1	-3	-3
111-120	1	-1	-2	-3	-3
121-130	0	-2	-3	-3	-3
131-140	0	-3	-3	-3	-3

Blood Pressure Data Sheet

Measurement	1	2	3	Average
Systolic				
Diastolic				

Fitness Data Sheet

	Measurement	Points
Test 1. Change in systolic pressure from reclining to standing	mm Hg	
Test 2. Standing Pulse Rate	beats/min	
Test 3. Reclining Pulse Rate	beats/min	
Test 4. Baroreceptor reflex Pulse Rate increase on Standing	beats/min	
Test 5. Return of Pulse Rate to Standing after Exercise	seconds	
Pulse Rate increase immediately after exercise	beats/min	
	Total Score	

Total Score	Relative Cardiac Fitness
18-17	Excellent
16-14	Good
13-8	Fair
7 or less	Poor

Topics for Discussion

1. Explain why blood pressure and heart rate differ when measured in a reclining position and in a standing position.
2. Explain why high blood pressure is a health concern.
3. Explain why an athlete must exercise harder or longer to achieve a maximum heart rate than a person who is not as physically fit.
4. Research and explain why smoking causes a rise in blood pressure.

Part II: Daphnia Heart Rate

Go to the following URL to view the beating heart of a daphnia.

http://ebiomed.com/gall/classics/Daphnia/daphnia_behave2.html

Questions:

1. What is the common name for the daphnia?
2. What is Q10?
3. How would increasing temperature by 10 C likely influence the heart rate of the daphnia?
(Hint: Remember the Goldfish!)

