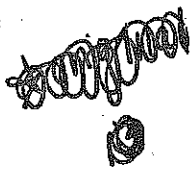
Class Set – Please Return!

Cardiovascular Fitness Lab

OBJECTIVES

When you have completed this lab, you should be able to do the following:

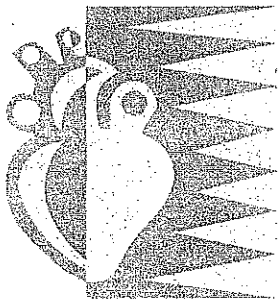
- Measure heart rate and blood pressure in a human volunteer
- Describe the effect of changing body position on heart rate and blood pressure
- Explain how exercise changes heart rate
- Determine a human's fitness index
- Analyze pooled cardiovascular data
- Discuss and explain the relationship between heart rate and temperature



This lab will be conducted in three parts:

1. **Harvard Step Test**: a cardiovascular endurance test used to measure cardiac fitness
2. **Effect of Position on Blood Pressure**: to measure relative cardiac fitness based on blood pressure changes upon change in body position
3. **Effect of Environment on Q_{10}**: Analyze data collected from organisms placed in different temperatures to see how temperature affects heart rate. You will do this part on your own, outside of class.

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.

CARDIAC FITNESS

The **Harvard Step Test** is a type of cardiac stress test for detecting and/or diagnosing cardiovascular disease. It also is a good measurement of fitness, and your ability to recover after a strenuous exercise. The more quickly your heart rate returns to resting, the better shape you are in.

The Harvard Step Test was developed by researchers at Harvard University during World War II in order to test the cardiovascular fitness of military recruits, and today is used to gauge an individual's relative cardiac fitness. The test computes the capability to exercise continuously for extended intervals of time without tiring, so it is a test of endurance.

The test is conducted by having a person step up and down on a platform at a height of about 45 cm. at a rate of 30 steps per minute for 5 minutes or until they reach a state of exhaustion. Exhaustion is the point at which the

subject cannot maintain the stepping rate for 15 seconds. The subject immediately sits down on completion of the test, and the heartbeats are counted for 1 to 1.5, 2 to 2.5, and 3 to 3.5 minutes. Then the recovery index (RI) is calculated as follows:

$$\textbf{Recovery Index (RI)} = \frac{\text{Duration of exercise in seconds} \times 100}{\text{Sum of pulse counts} \times 2}$$

The resulting value is then compared to the chart below:

Cardiac Fitness Rating Using Harvard Step Test

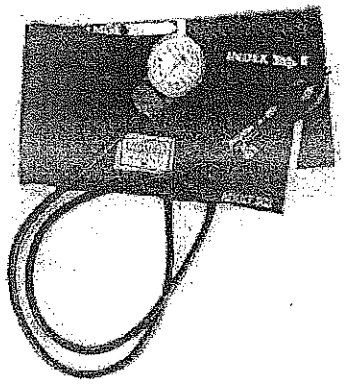
Gender	Excellent	Above Average	Average	Below Average	Poor
Male	>90	80-90	65-79	55-64	<55
Female	>86	76-86	61-75	50-60	<50

Table Reference: McArdle W.D. et al; Essential of Exercise Physiology; 2000

There are several factors that can influence the results of the Harvard Step Test, such as height of the bench stepped on as well as weight and height of the subject, so the relative cardiac fitness of an individual is not measured solely based on this test.

BLOOD PRESSURE

An important measurable aspect of the circulatory system is **blood pressure.** When the ventricles of the heart contract, pressure is increased throughout 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 (mm Hg). 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 is evident 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 that 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 (that is, the beginning of Phase 1) is taken as the systolic pressure. The cuff pressure with the muffled sound (Phase 4) disappears (the 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, kidney disease and stroke.

A healthy blood pressure is defined as one whose systolic value is less than 120 mm Hg and whose diastolic value is less than 80 mm Hg.

The American Medical Association recently revised its guidelines regarding what constitutes hypertension. The chart is given below:

Pressure	Normal BP	Prehypertension	Stage I Hypertension	Stage II Hypertension
Systolic	≤ 120	120-139	140 -159	≥ 160
Diastolic	≤ 80	80-89	90 - 99	≥ 100

From http://www.medicinenet.com/script/main/art.asp?articlekey=23356

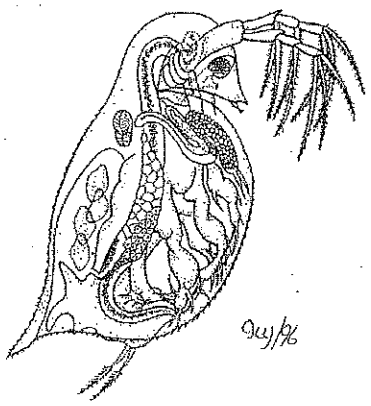
Table 10.1: Normal Blood Pressure for Men and Women at Different Ages

	Systolic Pressure		Diastolic Pressure	
Age in Years	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

Q_{10}

Q_{10} is a thermodynamic measure of the increase in metabolic activity resulting from an increase in body temperature Q10 will vary among organisms that are **endothermic** or **ectothermic**. Organisms which are endotherms internally regulate their temperature and do not rely on the outside environment to regulate it for them. Mammals and birds are both endothermic organisms, as neither of them rely on their environment to directly regulate their body temperature. Their body temperatures remain constant, regardless of the temperature changes around them. This characteristic also makes them **homeotherms**. Mammals use a part of their brain called the **hypothalamus** to regulate their body temperature.

Organisms which rely on their external environment to regulate their body's temperature are known as ectotherms. These organisms rely on things such as sunlight, or water currents in order to maintain a certain body temperature. For example, when a lizard suns itself on a rock in the midday sun, it is relying on the radiant heat of the sun to regulate its body temperature. Another example is turtles that bury themselves in cool mud to cool themselves off when it is hot outside.



Organisms such as the water flea, *Daphnia* (shown at left) can adjust their temperature to the environment. Organisms with this ability are known as **poikilotherms** (from the Greek *poikilo-* meaning "varied"). As the temperature in the environment increases, their body temperature also increases. This in turn increases their heartbeat rate per minute.

Now you will explore each part of the lab in class today. Be sure to read the directions for each part carefully and completely before beginning.

NOTE: Any measurement of blood pressure or heart rate taken during this lab is to be used for data gathering, NOT diagnostic purposes. If you think that you have a cardiac condition, please see your personal physician. Also, if you have a medical condition that prohibits you from participating in any part of this experiment, notify your teacher.

Procedure A: Standing Pulse Rate

1. The subject should stand at ease for 2 minutes.
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. **Repeat this procedure three times to get an average pulse rate.** Record this on the data sheet. Assign fitness points based on Table 10.2 and record them on the data sheet.

Table 10.2: Fitness points assigned to various heart rates

Average 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

Procedure B: Reclining Pulse Rate

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. Record it on the Data sheet. Assign fitness points based on Table 10.3 and record them on the data sheet.

Table 10.3: 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

Procedure C: Baroreceptor Reflex (Pulse Rate Increase from Reclining to Standing)

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 heartbeat, and consequently the pulse rate.
3. Subtract the reclining pulse rate (recorded in procedure B) 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 10.4 and record on the data sheet.

Table 10.4: 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

PROCEDURE D: Harvard Step Test

1. Step up on to a standard gym bench (45cm high) once every two seconds for five minutes (~150 steps). Start with one foot (right or left) and use that same foot as the starting "step up" foot throughout the exercise.
2. Have someone to help you keep to the required pace. A counter or metronome can be helpful to maintain the rate (120 count on a metronome).

3. One minute after finishing the test take your pulse rate for 30 seconds to get Beats per Minute (bpm). Have the person refrain from talking and unnecessary movement when heart rates are being counted since any activity can skew the heart rate and influence the results - Pulse 1
4. Two minutes after finishing the test take your pulse rate for 30 seconds (bpm) - Pulse 2
5. Three minutes after finishing the test take your pulse rate for 30 seconds (bpm) - Pulse 3
6. Record your data in the appropriate location on the data sheet and figure out what your recovery index value is.

Procedure E: Heart Rate and Physical Fitness—Running in Place (Endurance)

During physical exertion, the heart rate (beats per minute) increases. This increase can be measured as an increase in pulse rate. Although the maximum heart rate is usually the same in people of the same age group, those who are physically fit have a higher **stroke volume** (milliliters per beat) then more sedentary individuals. A person who is in poor physical condition, therefore, reaches their maximum heart rate at a lower work level than a person with of comparable age who is in better shape. Maximum heart rates are listed in Table 10.5. Individuals who are in good physical condition can deliver more oxygen to their muscles before reaching maximum heart rate than can those in poor condition.

Table 10.5: Maximum Heart Rate

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

Procedure

1. Jog in place vigorously for 2 minutes, being sure to lift each foot off the ground **at least** 8-10 inches with each step.
2. Immediately after the completion of the exercise, measure the pulse for 15 seconds and record on the data chart. Measure again for 15 seconds and record; continue taking the pulse and record at 60, 90, and 120 seconds.
3. Observe the time that it takes for the pulse rate to return to approximately the level as recorded in Test A. Assign fitness points based on Table 10.6 and record them on the data sheet.

Table 10.6: 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 A) from your pulse rate immediately after exercise (the 0-to 15-second interval) to obtain pulse rate increase. Record this on the data sheet. Assign fitness points based on Table 10.7 and record them on the data sheet.

Table 10.7: Pulse Rate Increase Immediately After Exercise

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

PROCEDURE F: Blood Pressure Upon Positional Change

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. The earpieces of the stethoscope should be cleaned with alcohol swabs before and after each use. We may also use automated blood pressure cuffs of either the brachial (upper arm) or radial (wrist) variety, neither of which require the use of a stethoscope.

Procedure for manual blood pressure measurement: You need to be silent so that the pressures can be heard!

1. Work in pairs. Those who are to have their blood pressure measured should be seated with both shirtsleeves rolled up.
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 180 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. When your average systolic and diastolic pressure have been determined, record these values on the blood pressure data sheet.

Procedure for automated blood pressure cuff measurement:

1. Place the cuff in the appropriate location—upper arm for brachial measurement, wrist for radial measurement.
2. Follow the directions provided by the machine, reminding your subject to remain quiet and still the entire time. Any movement will disrupt data collection.
3. After the allotted time has passed, collect the data from the machine and clear it for use on another test subject. Record the data on the blood pressure data sheet.

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 and then repeat the process for the other member of the pair.

Procedure

1. The subject should recline on a laboratory bench for **5 minutes**. At the end of this time, measure the systolic and diastolic pressure and record these values on the blood pressure data sheet.
2. Remain reclining for two minutes, then stand and IMMEDIATELY repeat measurements on the same subject (arms down). Record these values on the blood pressure data sheet.
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 10.8 and record in the appropriate space on the data sheet.

Table 10.8: 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

PROCEDURE G: Q_{10} Measurements

Use the website http://www.phschool.com/science/biology_place/labbench/lab10/temprate.html to answer the questions through the *Daphnia* simulation (simulation 10-II) shown at the site. Answer the questions on a separate sheet of paper and attach them to the Analysis Questions for this lab. Make sure you go through each part of the simulation, including Key Concepts and Design of the Experiment.