LABORATORY 3
Physiological Mechanism of Homeostasis
OVERVIEW OF LAB

**Homeostasis**, the ability to maintain a stable internal environment, is a major characteristic of living organisms. In this exercise, we will examine some homeostatic mechanisms. The exercise examines adjustments in the cardiovascular system of human subjects.

HUMAN CARDIOVASCULAR PHYSIOLOGY

In order to maintain homeostasis cells must exchange nutrients and wastes with the external environment. In single celled organisms acquisition of nutrients and removal of wastes occurs directly across the cell membrane. However, the cells of complex organisms are isolated from the external environment and normal cell homeostasis must be maintained by coordinated function of specialized organ systems. In mammals, the cardiovascular system functions to allow exchange between cells and the external environment by transporting blood throughout the different tissues of the body. For example, blood is delivered to the lungs where oxygen is provided from the external environment and delivered to cells. Conversely, CO$_2$ generated by cells is released into the blood and transported to the lungs for elimination into the external environment. Other wastes are transported by the cardiovascular system to the kidneys and liver to enable excretion from the body. Nutrients from the diet are picked up from the digestive system by the cardiovascular system and distributed to cells for storage and use. The cardiovascular system also functions in the delivery of chemical signals within the body which enables coordination of function between different organ systems.

Blood flows throughout the body as a result of a pressure difference generated by the pumping of the muscular heart. The mammalian heart consists of 2 atria or receiving chambers and two ventricles or pumping chambers. At rest, the heart normally beats 70-75 times per minute. The **cardiac cycle** includes the electrical, mechanical and valvular events that occur during one heartbeat. **Diastole** is the period of the cardiac cycle during which the ventricles are relaxing, and **systole** is the period during which the ventricles are contracting.

During systole blood is pumped from the heart into arteries which branch extensively and terminate in arterioles which actively change in diameter to regulate blood flow to different regions of the body. Blood flows from arterioles into thin-walled capillaries which are adapted for exchange of nutrients and waste. Blood is returned from capillaries to the heart by compliant veins. Delivery of blood by the cardiovascular system may be varied physiologically by varying function of either the heart or blood vessels.

The objectives of this lab are: 1) to become familiar with some of the measurements that are used to assess human cardiovascular function including auscultation of heart sounds, palpation of the peripheral pulse and
indirect measurement of blood pressures; 2) to examine the influence of "conditioning" on the cardiovascular responses to exercise.

**AUSCULTATION HEART SOUNDS**

The heart chambers are separated by four valves which function to prevent backflow of blood. The atria and ventricles are separated by the atrioventricular valves. The right ventricle and left ventricle are separated from the pulmonary artery and aorta, respectively, by the semilunar valves (see text for diagrams). Closing of the valves in the heart results in the production of sounds associated with changes in the direction of blood flow. Two of the four normal heart sounds can be heard clearly using a stethoscope. The first heart sound \( s_1 \) or "lub" is associated with the closure of the AV valves, and the second heart sound \( s_2 \) or "dup" is associated with closing of the semilunar valves. Abnormal heart sounds called **murmurs** are often caused by defects in one or more of the valves.

**Activity:**

Obtain a stethoscope, clean the earpieces with an alcohol wipe and listen to either your own or a lab partner's heart sounds. There are four major areas of the chest where the sounds from each valve are most distinct.

**Hint:** The earpieces of the stethoscope are angled. The earpieces should be angled in a forward direction to facilitate the best auscultation.

*Where in the cardiac cycle do \( s_1 \) and \( s_2 \) occur?*

*Describe the intensity or pitch of \( s_1 \) and \( s_2 \), and explain any differences.*

**PALPATION OF SUPERFICIAL PULSE POINTS**

As the heart ejects blood into the arteries during systole the arteries expand, and because arteries contain elastic tissue they recoil during diastole. This alternating expansion and recoil creates an arterial **pulse** which normally equals the **heart rate**. In addition to providing a measure of the heart rate, the quality of the pulse (regularity and strength) also provides important functional information.

**Activity:**

The pulse may be easily detected from any superficial artery when the artery is compressed against firm tissue. Palpate the following superficial pulse points:

- Common carotid artery: lateral to the Adams apple in the neck
- Brachial artery: in the antecubital fossa (inside the elbow)
- Radial artery: inside the wrist near the thumb.
Record your baseline (resting) pulse rate in beats per min. (Take 3 measurements & their average.)

Baseline Pulse Rate: _______ _______ _______ avg.: _______

**INDIRECT MEASUREMENT OF BLOOD PRESSURE**

Evaluation of arterial blood pressure is a very useful clinical measurement which provides information regarding both function of the heart and condition of the blood vessels. The following pressures are commonly measured or calculated:

- **Systolic blood pressure**: The maximal pressure in an artery produced during the ejection of blood by the heart. Normal average resting pressure for young adults: ~120mmHg.

- **Diastolic Blood Pressure**: The minimal pressure in an artery occurring when the heart is relaxed. Normal average resting pressure for young adults: ~70mmHg.

- **Pulse Pressure**: Difference between the systolic and diastolic pressures.

- **Mean Arterial pressure (MAP)**: The average pressure in the arteries across the entire cardiac cycle. Mean Arterial pressure be estimated as (diastolic pressure + 1/3 the pulse pressure). The MAP represents the mean force driving blood through the circulatory system and is determined by the function of the heart (cardiac output) and the resistance to blood flow through the blood vessels (total peripheral resistance).

  \[
  \text{MAP} = \text{cardiac output (mls/min)} \times \text{Total peripheral resistance (TPR units)}.
  \]

**Cardiac output** is the volume of the blood pumped by the heart per minute, and may be increased by increasing the force generated by the heart muscle or by increasing the heart rate. **Total peripheral resistance** depends primarily on the radius of arteries and arterioles, but may also be altered by changes in blood viscosity.

Blood pressure may be measured directly via a pressure transducer attached to a cannula placed in a blood vessel. However, arterial blood pressure is more commonly measured indirectly by applying a pressure externally to an artery using a sphygmomanometer and listening to arterial sounds using a stethoscope. The basis of this method is that normal blood flow through an artery is laminar and does not create a sound. However partial occlusion of a blood vessel creates intermittent flow and turbulence which can be heard (auscultated) using a stethoscope. The sounds produced when a cuff is used to apply pressure externally to an artery were first described by Korotkoff in 1905 and are referred to as the sounds of **Korotkoff**. Human blood pressures are most commonly measured in the brachial artery of the upper arm.

**Activity:**

Have the subject seated with her arm resting on the lab bench. Wrap the pressure cuff around the upper arm and secure the cuff (be certain that the inflatable bag is placed over the inside of the arm with the arrows over
the artery). Turn the valve on the cuff clockwise to close it. Place the bell of the stethoscope over the brachial artery below the cuff. Prior to inflating the cuff no sounds can be heard. Inflate the cuff to approximately 160mm Hg.

**Note: do not leave the cuff inflated for more than 1 minute.** This pressure is above the normal systolic pressure completely collapsing the artery so that no sounds are heard. Open the valve by turning it counterclockwise to slowly lower the pressure in the cuff. As the pressure is decreased you will be able to hear the following sounds of Korotkoff:

**Phase 1:** A sharp thudding sound will appear when the pressure in the cuff is equal to the **systolic pressure**. The sound is produced by the turbulence of intermittent blood flow through the artery.

**Phase 2:** A softer murmur is produced as blood flows through the artery during more of the cardiac cycle.

**Phase 3:** The sounds become louder again as turbulence increases.

**Phase 4:** The sounds become muffled and less intense and finally disappear entirely. The pressure during this phase is the **diastolic pressure**. The sounds disappear as the blood flow through the vessel becomes continuous and laminar. There is some controversy regarding whether the pressure should be noted as the sound becomes muffled or as it disappears. It is recommended that you use the pressure at the point at which the sound can no longer be heard.

You should practice taking blood pressure until you can easily detect the systolic and diastolic sounds. Note that measuring blood pressures in individuals in which vessels are located deeper in body tissues may be difficult.

**CARDIOVASCULAR ADAPTATION TO EXERCISE**

During exercise the demand for blood flow to the heart and exercising muscles increase to several times the resting demand.

**Hypothesis:** “Conditioned” individuals have more efficient cardiovascular systems than “unconditioned” individuals.

*Formulate specific predictions about: 1) differences in resting heart rates; 2) differences in how quickly the cardiovascular systems of individuals should return to a resting state after exercise.*

**Experimental Exercise:**

You should work in groups of 4 to complete the following experiment. **Note: any student with a heart problem or other medical problems should not participate as a subject.** Subjects should be divided into two groups. Conditioned: students who participate regularly in endurance exercise (>30 minutes X 3
times/week) and unconditioned: students who do not participate regularly in endurance exercise. The exercise test is a standard protocol known as the Harvard Step Test.

1. Record baseline pulse rate with the subject seated.
2. Perform the step-test: The subject should stand in upright posture at a bench of prescribed height, which is 20 inches (51 cm) for males and 16 inches (40 cm) for females. The subject will step up and down on the bench at a rate of 30 steps per minute (all the way up and down equals one step) for as long as possible up to 5 minutes. If no metronome is available, then the pace should be set by a timer who will call "up-2-3-4, up-2-3-4" so that each "up-2-3-4" requires 2 seconds. A second observer must monitor the subject to ensure that she steps fully on the bench maintaining an upright posture and that she maintains the pace. If the subject fails to maintain the pace for 10-15 seconds then the observer should stop the exercise test.
3. When the subject completes 5 minutes of exercise, stops voluntarily, or is stopped by the observer she should sit down. The duration of the exercise should be recorded and the pulse rate should be measured immediately, and at 1 minute intervals 3 minutes following the exercise test.
4. Calculation of the Index of Physical Fitness:

   \[
   \text{Fitness Index} = \frac{\text{Duration of exercise (in seconds)}}{2 \times (\text{Sum of the 3 pulse counts during recovery})}
   \]

**TABLE 1. Group Data: pulse rates (beats/min.) & fitness index values of conditioned © & non-conditioned (NC) individuals**

<table>
<thead>
<tr>
<th>Subject: C or NC</th>
<th># of seconds</th>
<th>Baseline Pulse Rate</th>
<th>Immediate Pulse Rate</th>
<th>1 min. pulse rate</th>
<th>2 min. pulse rate</th>
<th>3 min. pulse rate</th>
<th>Fitness Index</th>
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TABLE 1. Group Data: pulse rates (beats/min.) & fitness index values of conditioned © & non-conditioned (NC) individuals
### TABLE 2. Whole Class Data.

<table>
<thead>
<tr>
<th>Conditioned</th>
<th>Non-Conditioned</th>
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<tbody>
<tr>
<td><strong>PULSE RATE (BASELINE)</strong></td>
<td>MEAN S.D.</td>
</tr>
<tr>
<td><strong>PULSE RATE (IMMEDIATE)</strong></td>
<td>MEAN S.D.</td>
</tr>
<tr>
<td><strong>FITNESS INDEX</strong></td>
<td>Mean S.D.</td>
</tr>
</tbody>
</table>

- t-test comparison of Baseline Pulse Rates; p-value: ________________
- t-test comparison of Imm. Pulse Rates; p-value: ________________
- t-test comparison of Fitness Index; p-value: ________________
LAB. REPORT

In your Results section be sure to include:

1. Calculations of the mean and standard deviation of the fitness index and pulse rates (baseline & immediately post exercise) for conditioned and non-conditioned individuals.
2. Bar graphs with error bars plotting the means and standard deviations for the pulse rates for baseline and immediately after exercise, and for the fitness index values.
3. t-tests comparisons of the pulse rate (baseline, "immediate") & fitness index values for conditioned & non-conditioned individuals.

In your Discussion section be sure to include an analysis showing whether the data and statistical tests support you predictions. Also:

- Relate the observed changes in pulse rates to the increased demand for blood flow during exercise;
- Relate your findings to cardiovascular differences brought about by conditioning;
- Note any flaws in the lab. procedure that may have influenced the results.

Note that your instructor may provide you with data from other lab sections to improve the power of the statistical analyses.

In your Literature Cited section be sure to include the two references listed below as well as any other references requested by your instructor.

**Literature Cited**
