ASPECTS OF ANIMAL PHYSIOLOGY

I. Background

Underlying all of Animal Physiology is the concept of Homeostasis. By Homeostasis we mean the ability of living things to maintain their internal environment or “milieu interieur” in a state of physical and chemical constancy, which is conducive to the continued efficient life of the individual cells of the body. Usually that milieu interior is the primary body fluid, as for example the blood of vertebrate animals.

The concept owes its origin, in the mid 1800’s, to the work of the French Physiologist Claude Bernard who, to distinguish natural Physiology from the Greek concept of “vital forces” wrote:

“The fixity of the milieu supposes a perfection of the organism such that the external variations are at each instant compensated for and equilibrated.... All of the vital mechanisms, however varied they may be, have always one goal, to maintain the uniformity of the conditions of life in the internal environment.... The stability of the internal environment is the condition for the free and independent life.”

The idea was later taken up by the American Walter Cannon, who expanded the concept, mechanistically, to give it wide acceptance and dubbed it “Homeostasis”.

The idea that the animal body can naturally detect and respond to environmental changes, both external and internal, and respond to them with a return to “normalcy” implies the existence of internal “Control Systems”.

Basically such control systems should include:

- A variable – a chemical or physical parameter of the body that can change over time.
- A Sensor – a device or organ that can detect changes in a given variable.
- A Control Center – this component functions by comparing the actual value of the variable to its “set point” or optimum value, and generating an “error message” when the two fail to match.
- An Effector – this is a system that will respond to the error message from the control center and return the variable to its set point.

In the animal body the milieu interieur is often considered to be the body fluids, especially the “blood”. Components that can vary include; its pressure, temperature, gas content, nutrient content, waste content, pH etc. Sensors include specialized receptor cells that are responsive to physical or chemical components and/or their associated “nerve endings”.
The primary Control Center of the body is an expanded region of the nervous system known as the Brian. Secondary controls are in the spinal cord, the endocrine system and in “nerve nets” built directly into particular organs or organ systems. The Effectors are generally the “maintenance systems” of the body, such as the respiratory, circulatory, digestive and excretory systems. Additional effectors can be in the muscular and skeletal systems if the response requires animal movement (as to obtain food for the digestive system to process).

Central among the maintenance systems is the circulation. This system is charged with the responsibility of distributing the liquid “milieu” (blood) to all the cells of the body. A main factor in the distribution is the provision of all cells with the means to maintain their energy levels. In this regard the circulation must be coordinated with the (intermittent) digestion and constantly with the respiratory system to supply the fuel and oxygen needed to burn that fuel, to the body cells. Thus the circulatory system must be highly responsive to changing conditions. In this lab we will examine some of the properties and responses of the cardiovascular and respiratory systems.

II. Objectives
After completing this exercise you should:
1) Be familiar with the general composition of blood.
2) Be able to monitor your pulse, blood pressure and breath rate.
3) Be able to predict how such parameters will change in response to environmental changes.

III. Exercises
A. Analysis of Blood
Blood is the basic medium of the milieu interieur. As such a great deal can be learned about the physiology of an individual by examining its composition. It is for this reason that your physician orders many “Blood Tests” when attempting to diagnose medical problems. Today, however, we will examine only a few basic properties of Blood.
1. Composition of Blood - Hematocrit
Blood is composed of a water based liquid, called the plasma and the formed elements. Each can be analyzed further with ions, proteins, hormones, gasses, nutrients and wastes dissolved in the plasma and the formed elements divided into red blood cells (RBCs) and white blood cells (WBCs). If a sample of blood is centrifuged its components will separate by density allowing the determination of the proportion of the volume occupied by each component. The % volume occupied by the RBCs is referred to as the hematocrit and is an indication of the Oxygen carrying capacity of the Blood. Originally this was done in common centrifuge tubes, but modern labs use calibrated and treated capillary tubes and a special centrifugation apparatus. In
the absence of these and to avoid having to poke yourself to draw blood we will simply demonstrate using a common figure.

Observe that after centrifugation the tube has three layers; an upper amber colored liquid – the plasma, a small off-white layer called the “buffy coat” which represents WBCs and platelets, and a deep red lower layer which is found to consist of red blood cells (RBCs). Obtain a ruler and measure the total height of the solution in the left tube. Then measure the height of the individual layers in the right-hand tube. Now calculate the % “packed cell volume” (PCV) for the components. (Note: since the diameter is constant the volume is proportional to the heights) Fill in the Table below.

<table>
<thead>
<tr>
<th>Blood Elements</th>
<th>Height (cm or mm)</th>
<th>% PCV</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBCs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WBCs and platelets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plasma</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>
Knowing that in the U.S. the normal hematocrit values for males range from 42% to 52%, and that for Females is from 37% to 47%, which sex do you suppose our test sample represents?

What do you suppose is the “proximate” cause of the difference in hematocrit between males and females and what anatomical difference is it likely to support?

Usually WBCs constitute about 1% of the Blood Volume. Does your measurement support this?

Suppose the “Buffy Coat” volume was slightly elevated. What might that indicate for the health of the individual who donated the blood sample?

Suppose that the Buffy Coat volume was substantially elevated. Might that have a different cause that a slight elevation and what might that be?

2. Blood Cells

The proper term for RBCs is erythrocytes. They function in the transport of the gasses O₂ and CO₂. The proper term for WBCs is leukocytes. They function in body defense. There are five basic types of leukocytes (see below)

Obtain a prepared slide of human blood and examine it first at low power to get an overall impression and then at high power (40x). Using the generalized picture below attempt to identify and draw a picture of a real representative of each blood cell type.
Which type of blood cells are stained pink?
Do you see their nuclei?
What “pigment protein” is likely to be present in these cells and what is its function?

What proportion of the cells appears to be leukocytes?
What proportion of the leukocytes is granular?
Speculate on the function(s) of the granules.

Which leukocyte is most abundant?

Suppose that you found a sample from an individual where the proportion of the different leukocytes varied from the norm (had an altered “differential”). What might that lead you to conclude and/or do for this hypothetical patient?

If available examine a sample of diseased (e.g. sickle cell) blood and note the differences.
3. Blood Types – a Demonstration

The white blood cells function in body defense. Some act as generalized phagocytes, devouring invaders and some, such as the lymphocytes mount a defense that is specific to a particular invader. Particular invaders are identified by their “antigens”, usually unique proteins or carbohydrates on their surface. B-Lymphocytes elaborate “antibodies” that function to bind antigens and thereby inactivate the foreign invader. You should note, however, that an antigen is not something peculiar to pathogenic organisms. Rather it is any material that is not produced by a particular organism i.e. anything foreign. Thus an antibody can be raised to any “foreign” substance, even those produced by other human beings.

Your blood type is determined by your genes. These genes code for the production of distinct glycoproteins on the surface of your red blood cells. Thus they will be exposed to antibodies, if any are present. The primary blood groups are A, B, O and the Rh+, Rh- varieties. In many (but not all) cases an individual with A-Type blood will also carry Anti-B antibodies (and vice versa). Thus a transfusion from an A-Type to a B-Type individual will result in an “antibody-antigen” reaction and the rejection of the transfused blood. Indeed, a procedure designed to help an injured individual may lead to their death. Thus “Blood Typing” is routinely done prior to any transfusion. (Likewise donor and recipient must be tissue-typed prior to any transplant.) The figures below show the background and outline of the determination of the basic Blood Types. Your TA will provide a demonstration reaction for you to analyze (this minimizes the hazards of blood-letting in the lab).
<table>
<thead>
<tr>
<th>Type A</th>
<th>Type B</th>
<th>Type AB</th>
<th>Type O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antigen A</td>
<td>Antigen B</td>
<td>Antigen A and B</td>
<td>Neither A nor B antigens</td>
</tr>
</tbody>
</table>

**Red blood cells**

**Plasma antibodies**

<table>
<thead>
<tr>
<th>Incidence:</th>
<th>Caucasian</th>
<th>African-American</th>
<th>Native American</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>40%</td>
<td>27%</td>
<td>8%</td>
</tr>
<tr>
<td>U.S.</td>
<td>10%</td>
<td>20%</td>
<td>1%</td>
</tr>
<tr>
<td>African-American</td>
<td>5%</td>
<td>4%</td>
<td>0%</td>
</tr>
<tr>
<td>Native American</td>
<td>45%</td>
<td>49%</td>
<td>91%</td>
</tr>
</tbody>
</table>

**Figure 14.5** Characteristics of ABO blood types.

**Blood being tested**

- **Type AB (contains agglutinogens A and B)**
- **Type B (contains agglutinogen B)**
- **Type A (contains agglutinogen A)**
- **Type O (contains no agglutinogens)**

**Serum**

- **Anti-A**
- **Anti-B**

**RBCs**

**F29.9**

Blood typing of ABO blood types. When serum containing anti-A or anti-B agglutinins is added to a blood sample, agglutination will occur between the agglutinin and the corresponding agglutinogen (A or B). As illustrated, agglutination occurs with both sera in blood group AB, with anti-B serum in blood group B, with anti-A serum in blood group A, and with neither serum in blood group O.
B. The Cardiovascular System
The cardiovascular system is composed of the Heart and Blood Vessels. Pictures and diagrams of the basic components are provided below.
Use the diagram below to trace out and number the pattern of blood flow through the heart. (You should have about 14 steps, but some numbers e.g. equivalent blood vessels, may appear multiple times.)

1. **Heart Sounds**
   The heart goes through a series of activities called the Cardiac Cycle for each “beat” of the heart. These activities include; generation and propagation of electrical signals, expansion and contraction of the atria and ventricles, and the operation of the heart valves, which maintain directional blood flow.

   Two distinct heart sounds can be heard during each cardiac cycle. These heart sounds are commonly described as “lub” and “dup”; and the sequence is lub-dup, pause, lub-dup, pause and so on. The first heart sound (lub) occurs as the AV valves (see above) close at the beginning of “systole” (ventricular contraction), and the second sound (dup) at the end of systole as the semilunar valves into the blood vessels close. We will now try to determine whether we can hear and discriminate variations in these sounds.
Here we will “auscultate” (listen to) heart sounds with an ordinary stethoscope.

Obtain a **stethoscope** and rinse the ear pieces with an alcohol swab. Note: the ear pieces should be angled forward for best comfort and hearing when placed in the ear for use.

It is often easier, particularly for the amateur, to hear these sounds when the stethoscope “bell” is placed directly on the skin. As this may require the removal of the outer garment it is preferable that the subject, here, be male.

Don the stethoscope and place its diaphragm (bell) on the subject’s chest, just to the sternal (breast-bone) side of the left nipple at the 5th intercostals space. Listen carefully for heart sounds. The first sound should be longer, and louder (more booming) than the second, which is short and sharp.

Try to time the pause between the end of the second sound and the beginning of the first of the next heart beat. How long is this interval? ______

Now try to determine a heart rate by counting the number of “beats” for one minute. Heart rate ____________

We will now see if you can detect any differences in the individual valves. Place the stethoscope at the apex of the heart (mitral valve position above). Listen carefully to distinguish the sound of the mitral valve. Now move the “scope” to the midline (tricuspid valve position), and listen again. Can you detect a slight timing mismatch in the actions of the two heart valves? ____
There is also a slight timing mismatch in the actions of the semilunar valves. Here, detection can be enhanced by having the subject inhale deeply but gently as you listen. Listen at the two positions noted above for the two valves. Can you now detect the timing difference?

Note an oddity of the “best positions” for the semilunar valves. That for pulmonary artery, which comes off the right heart is on the left and the position for the aorta, which comes off the left heart is on the right. Explain why this is so.

2. Pulse and Blood Pressure
   The Pulse refers to the alternating surges of pressure that occur in a peripheral artery in correlation with the contractions and relaxations of the left ventricle. The pulse may be easily felt on any artery close to the body surface when the artery is compressed over a bone or other firm tissue. The diagram below shows some of the common pulse “palpation” points.

![Diagram of pulse palpation points](image)

The most commonly use point is the radial artery. The pulse point for the radial artery is located on the side of the wrist, above the thumb. Palpate this point by placing the fingertips of the first two or three fingers over the artery. It helps to compress the artery firmly as you begin and then ease up the pressure slightly. You should then begin to feel the pressure pulses traveling
along the artery. Once you are confident that you can feel the pulse, determine the heart rate by counting the pulses for 15sec and multiplying by 4. Repeat this twice to insure accurate measurement and record your observations below.

<table>
<thead>
<tr>
<th>Pulse Measurement</th>
<th>Your Rate beats/min</th>
<th>Lab Partner’s Rate beats/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial #1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial #2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trial #3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Parameters other than rate may also be useful clinically. Is the pulse regular, like the ticking of a clock, or does it seem to skip beats?

What is its strength or amplitude i.e. can you feel it strongly or is it hard to detect? Can you actually see the vessel expand?

Now try to feel the pulse at a few other locations e.g.
- Brachial – base of upper arm just above the point of junction
- Carotid – side of the neck
- Temporal – just anterior to the ear
- Dorsalis pedis - top of the foot, the artery loops (big toe side should be easiest)

Which pulse point had the greatest amplitude?

Which the least?

Can you offer any explanation for the difference?

**APICAL-RADIAL PULSE:**
Occasionally an apical-radial pulse study may be ordered. Here, the apical pulse is actually counted heart beats and the radial pulse is that taken from the lower arm. Generally the apical pulse is *slightly* faster than the radial due to the time it takes for the blood to rush to the extremities. However, any *large* difference, referred to as a “pulse deficit” is abnormal. Such a deficit may indicate cardiac impairment (weak output) or abnormal heart rhythms.

We will examine this property in groups of four. The first student will be the subject and will sit quietly to provide “resting level” data. The second student using a stethoscope over the 5th intercostals space will monitor the apical rate. The third student will monitor the radial pulse and the fourth student will be the timer and data recorder. Once both monitors indicate “ready” the timer
will call for “start” of count and time for one minute and then give the stop count indication. She/he will then record the finding of the monitors below.

Apical count __________ beats/min
Radial pulse __________ pulses/min
Pulse Deficit __________ pulses/min

BLOOD PRESSURE:
Blood pressure is defined as the force that the blood exerts on the inner walls of the blood vessels. It is usually measured in arteries where the pressure is greater. Because the heart rhythmically contracts and relaxes the force exerted by the blood varies over the cardiac cycle. Thus two blood pressures are usually measured; the systolic pressure, which is the pressure in the arteries at the peak of ventricular ejection of blood, and the diastolic pressure, the pressure during ventricular relaxation. The basic method of monitoring the blood pressure is show diagrammatically below and the procedure you will follow is then described.

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Procedure for measurement of blood pressure. (a) The course of the brachial artery of the arm. Assume a blood pressure of 120/70. (b) The blood pressure cuff is wrapped snugly around the arm just above the elbow and inflated until blood flow into the forearm is stopped and a brachial pulse cannot be felt or heard. (c) The pressure in the cuff is gradually reduced while the examiner listens (auscultates) carefully for sounds in the brachial artery with a stethoscope. The pressure read as the first soft tapping sounds are heard (the first point at which a small amount of blood is passing through the constricted artery) is recorded as the systolic pressure. (d) As the pressure is reduced still further, the sounds become louder and more distinct, but when the artery is no longer restricted and blood flows freely, the sounds can no longer be heard. The pressure at which the heart sounds disappear is routinely recorded as the diastolic pressure.
Taking a Blood Pressure Measurement – at “Rest” Pressure  
Refer to the diagram above as you follow these steps:

- Have the subject sit in a comfortable position with one arm resting on the lab bench, with the arm at the level of the heart if possible.
- Obtain a stethoscope and a **Sphygmomanometer**
- Palpate the brachial pulse and mark its position with a felt pen. Then place the diaphragm of the stethoscope over the marked point and listen for the sound of the pulse. It is unlikely that you will hear anything since the blood should be free flowing.
- Wrap the blood pressure cuff around the subject’s arm, just above the elbow. Often the inflatable area is on the medial side of the arm, with the indicator arrow (if present) above the brachial artery. Secure the cuff via its wrap or Velcro portion.
- Don the stethoscope and position the diaphragm over the marked brachial area. (See fig c above). As you carry out this procedure remember that the cuff should not be kept highly inflated on the arm for more than about one minute. (Prolonged interruption of blood flow can cause fainting) If you have trouble obtaining readings within this interval, deflate the cuff wait about 2 minutes and try again.
- While listening via the stethoscope, use the bulb to pump up the pressure to between 160-180mmHg as indicated on the scale. This pressure should be sufficient to compact the artery and prevent blood flow. Thus the pulse sounds should stop.
- Now open the valve slightly in order to slowly release the air from the cuff. This will reduce the pressure in the cuff and ultimately make it possible for the blood pressure to “open” the artery.
- At the point where the systolic pressure in the artery just matches the pressure in the cuff, blood should start to spurt through and the sounds of the “pulse” should resume. (Note: those with a “good ear” might first hear the sounds of the AV valves closing – this is a “tapping” noise and should be ignored. The true spurt of blood is somewhat louder – basically soft thudding sounds of the blood spurting through the partially blocked artery.) Mentally record, or call out the observed pressure at this point as the systolic pressure of the subject.
- As you continue to release the pressure in the cuff, you will first notice an increase in the sound, then a muffling, and finally the disappearance of the pulse sound (due to the renewed free flow of the blood through the now open artery). Record the point of disappearance as the diastolic pressure i.e. the pressure at the end of the cardiac cycle.
Make two blood pressure determinations, and record your results.

First Trial:                                          Second Trial:
Systolic Pressure _______________ Systolic Pressure ____________
Diastolic Pressure _______________ Diastolic Pressure ____________

You may now wish to repeat this, switching roles with your lab partner.

First Trial:                                          Second Trial:
Systolic Pressure _______________ Systolic Pressure ____________
Diastolic Pressure _______________ Diastolic Pressure ____________

“Standards” for Systolic and Diastolic Blood Pressure

<table>
<thead>
<tr>
<th>Systolic Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
</tr>
<tr>
<td>High-normal (borderline hypertension)</td>
</tr>
<tr>
<td>Stage 1 (mild hypertension)</td>
</tr>
<tr>
<td>Stage 2 (moderate hypertension)</td>
</tr>
<tr>
<td>Stage 3 (severe hypertension)</td>
</tr>
<tr>
<td>Stage 4 (very severe hypertension)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Diastolic Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
</tr>
<tr>
<td>High-normal (borderline hypertension)</td>
</tr>
<tr>
<td>Stage 1 (mild hypertension)</td>
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<td>Stage 2 (moderate hypertension)</td>
</tr>
<tr>
<td>Stage 3 (severe hypertension)</td>
</tr>
<tr>
<td>Stage 4 (very severe hypertension)</td>
</tr>
</tbody>
</table>

Were your dual determinations consistent? ________
If not, why do you suppose that was?

Is there any indication of **hypertension** in your lab group?

Might there be an alternate explanation for a high reading? What?

Why is hypertension dangerous if it is allowed to continue indefinitely?

In **atherosclerosis** (“hardening of the arteries”) plaque builds up on the artery wall. How might this effect blood pressure?
EFFECT OF POSTURE ON BLOOD PRESSURE AND PULSE

You may have noted that when your physician takes your pressure during a physical he/she routinely does so with you sitting, while they cradle your arm at about the level of the heart. This is to get consistent measurements. An alteration in posture can result in a change in cardiovascular activity thereby changing the blood pressure. We will briefly examine such an effect.

To do this simply and efficiently we will work in groups of four. One member will be the subject, one will measure blood pressure, one palpate the pulse and the remaining student will be responsible for controlling the timing and recording the data.

Step 1
The subject should get comfortably seated and don the blood pressure cuff. The blood pressure monitor should insure that the equipment is ready and they have located the proper listening point (if not already marked). Likewise the pulse taker should locate the radial pulse point of the arm on the opposing side. Now the subject should sit quietly for 2-3 min to insure a normal “resting” condition. When this condition is met the “timer” should call for the pulse and blood pressure to be determined and record the results.

Step 2
Now the subject should recline on the (cleaned) lab bench for about 5 min to establish a new postural condition. When it seems appropriate the “timer” will call for the blood pressure and pulse to be determined again, under these new conditions. Record your data.

Step 3
The subject should continue to recline quietly for another 2-3 min. Again the timer will call for the start of the next stage. Here, the subject will now stand erect, “at attention” for the next measurement. The “timer” is responsible for helping the subject up and stabilizing them in the upright posture. The blood pressure and pulse should be determined immediately upon standing. Record your result.

Step 4
The subject should remain standing for three more minutes and then the “timer” should call for the final measurement of blood pressure and pulse.
<table>
<thead>
<tr>
<th>Condition</th>
<th>Blood Pressure</th>
<th>Pulse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting Quietly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After reclining for 5 min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immediately upon standing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After standing for 3 min</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: in some studies this sequence would be repeated to assess consistency.

Did blood pressure and pulse change in the same or opposite direction upon standing?

Can you think of a physiological explanation (homeostatic compensation) for this observed response?

Do you think that a person’s degree of physical fitness might affect the degree of this response?

EFFECTS OF EXERCISE: Here we will outline a trial examining the effects of exercise on cardiovascular function, along with some additional respiratory measurements – in the next section of the lab. If your TA opts not to do the basic Respiratory studies, you can skip to the “Exercise” section now.

RESPIRATION
The respiratory system is responsible for the delivery and removal of “respiratory” gases \( \text{O}_2 \) and \( \text{CO}_2 \) respectively. In this activity it must cooperate with the cardiovascular system. Here, “breathing” or **pulmonary ventilation** is the process of moving air in and out of the lungs. There are two phases of breathing: **inspiration** (inhalation), during which the chest actively expands, creating a vacuum that induces air flow into the lung, and **expiration** (exhalation), when the chest passively contracts forcing air back out of the lungs. The amount of oxygen delivered to, and carbon dioxide removed from, the blood can be regulated by both the rate and depth of breathing. In this exercise we will examine a few aspects of the mechanics of “pulmonary ventilation”.

Respiratory (Breath) Sounds:
Bronchial sounds – place a stethoscope over the neck just below the larynx – this is the sound of air rushing through the large tubes.
Vesicular Sounds – result from the filling of the air sacs (a “rustling or muffled breeze”) – put the stethoscope over an intercostals space or on the back just medial to the “bottom” or the scapula.

Do you feel, from the quality of the sound, that your subject has some degree of “congestion”?

Determine the breath rate by counting the number of breaths in one minute. Breath Rate ____________

Can you determine the same breath rate, simply by observing (or feeling) the rise and fall of the chest?

RESPIRATORY VOLUMES AND CAPACITY
A person’s size, sex, age, health status and general physical condition can all influence their breathing mechanics. Ordinarily texts display the results for a healthy young male as the “standard”. One such display is shown here.

Lab measurements of respiratory volumes and capacities are carried out with an apparatus called a spirometer. There are dry, wet and fancy “recording” versions. We will be using a variety of the “Phipps and Bird” wet spirometer. (See Fig. below)
This consists of a plastic, open bottom, “bell” that rests in a tank of water. As air is added to the system the bell will float up higher above the water. This moves the pointer along the gage indicating the amount of added air. You should note that in such an apparatus the indicator only moves as air is exhaled into the chamber. Thus only expired air volumes can be measured directly.

We have only one such apparatus available, so we will only assess volumes for two subjects per lab section. These subjects should be chosen judiciously so that some reasonably appropriate physiologic comparisons/conclusions can be made/drawn e.g. two different size males/females, male vs. female, athlete vs. couch-potato, smoker/non etc.

The basic volumes are:
- **Tidal volume** (TV) – the amount of air in a normal inhale/exhale.
- **Inspiratory Reserve volume** (IRV) – the amount of air that can be forcibly inhaled after a normal inhalation.
- **Expiratory Reserve Volume** (ERV) – the amount of air that can be forcibly exhaled after a normal exhalation.
- **Residual Volume** – the amount of air always trapped in the lung.
- **Total Lung Capacity** (TLC) – the sum of the four above.
- **Vital Capacity** (VC) – the usable portion of the TLC or the sum of TV+IRV+ERV.

**MEASURING RESPIRATORY VOLUMES**
First count the number of breaths in one minute for the “resting” student subject. Normal “Resting” Respiratory Rate _______
This should be about 12 breaths/min.

Preliminary preparation:
Obtain a new cardboard tube mouthpiece and install it on the hose valve system of the spirometer. (Each subject should use a different mouthpiece) The subject should now take a few normal breaths and practice exhaling into the mouthpiece without exhaling through the nose. (If they cannot accomplish this either a nose clip or an alternate subject may be necessary.) Examine the gage and insure that you know how to read it properly. Remember that it can only determine exhaled volumes and **must be reset manually to zero after each trial**.
Tidal Volume (TV):
Have the subject relax and take 3 or 4 normal breaths. Now the subject takes a normal inhalation, places the tube in their mouth and exhales normally into the tube. Do not force the exhalation! Repeat the measurement twice more and record the results in the table below.

Expiratory Reserve Volume (ERV):
The subject should inhale and exhale normally 2 or 3 times. At the end of the last normal exhalation he/she should insert the mouthpiece and exhale forcibly as much additional air as they can. Repeat 2X more and record the results.

Vital Capacity (VC):
Again the subject should breathe normally 2-4 times. Now the subject should bend over while forcibly exhaling to exhale as much air as possible. Then as they rise to an upright position, inhale as fully as possible. (It is important to strain as you do so). Now, quickly insert the mouthpiece, and exhale as forcibly and completely as possible. Repeat this procedure two more times and record the results.

Inspiratory Reserve Volume (IRV):
IRV is usually calculated from the individual (or preferably averages) of the volumes determined above via the following formula.

\[ \text{IRV} = \text{VC} - (\text{TV} + \text{ERV}) \]

T | TV | ERV | VC | IRV |
--- | --- | --- | --- | --- |
1 |     |     |     |     |
2 |     |     |     |     |
3 |     |     |     |     |
Average |     |     |     |     |

You can now also calculate the “resting” minute respiratory volume (MRV) as:

\[ \text{MRV} = \text{TV} \times \text{Respiratory Rate} \]

T | TV | ERV | VC | IRV |
--- | --- | --- | --- | --- |
1 |     |     |     |     |
2 |     |     |     |     |
3 |     |     |     |     |
Average |     |     |     |     |

You can now also calculate the “resting” minute respiratory volume (MRV) as:

\[ \text{MRV} = \text{TV} \times \text{Respiratory Rate} \]
Do you notice any “trends” in the comparisons of your two subjects? What are they?

Do these trends follow your initial expectations? Why or Why not?

The Minute Respiratory Volume (MRV) that you have just determined is the “at rest” measurement. This value can be altered by a change in the physical activity of the subject. That is the topic that will be examined in the next segment of the lab.

EFFECT OF EXERCISE ON CARDIOVASCULAR AND RESPIRATORY ACTIVITY.
For this exercise we will work in groups of at least 4 (5 if that is more efficient). Two students will act as subjects. One will be responsible for Blood Pressure measurements, one for pulse and one for breathing rate and depth estimation. In addition either the pulse or breath monitor should also act as timer/data recorder/experiment coordinator. If, as seems most likely the two subjects are tested in sequence (rather than simultaneously) the untested subject can take one of the measuring roles for his/her companion subject.

Step 1
Choose the subjects to perform the exercises. Within the overall lab group you should try to get a mix of subjects of different apparent degrees of fitness etc. Anyone with a known heart or other cardiovascular condition should not function as a subject. These individuals should now sit quietly for a couple of minutes to establish an “at rest” condition.

Step 2
Those students chosen as “monitors” should now take baseline (at rest) measurements on the subject(s). These measurements should be taken as simultaneously as possible e.g. blood pressure and pulse determined on opposite arms. Breath rate and depth will need to be estimated from observation/listening. Some may find it convenient to listen to the breaths using the stethoscope on the subject’s back. Such observations will also assist in estimating depth. Since we do not have an instrument to take the measurement directly, we will simply categorize the depth as: shallow, normal, moderate, or deep. Obviously this “at rest” breath will set the standard for “normal” for this subject.
Step 3
Exercise: Two levels of exercise will be employed; mild and a more strenuous activity. It will probably be most efficient if these and their measurements are carried out in sequence. Subject one will do mild exercise e.g. about 30 sec – 1 min of raising alternate knees to the chest or jumping jacks etc. The second subject will run up and down the building stairs or about the “quad” in front of the building a couple of times.

Step 4
Immediately upon completion of the exercise the subject should don the cuff and have their blood pressure, pulse rate, and breath rate measured and the breath depth estimated. Note: posture should be the standard i.e. seated as during the “at rest” measurement.

Step 5
Retake all measurements during the recovery period at 2, 4, and 6 minutes post exercise.

Record all measurements in the table(s) below.

**Light Exercise**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Pulse</th>
<th>Blood Pressure</th>
<th>Breath Rate</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>At Rest</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Just Post Ex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 min post</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 min post</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 min post</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Strenuous Exercise**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Pulse</th>
<th>Blood Pressure</th>
<th>Breath Rate</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>At Rest</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Just Post Ex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 min post</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 min post</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 min post</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
At what point did you observe a greater elevation in blood pressure and pulse? __________________

What is a likely explanation of this physiologic effect?

What was the percentage difference of after exercise to resting pulse? Use \((\text{Post} – \text{Rest})/\text{Rest}\times100\)

Did and at what point did the post exercise rate return to the “rest” rate?

Did you note a sizable difference either in the percent change or the return to baseline between an “average” individual and one who you judge to be well conditioned?

What do you suppose accounts for such a difference?

How is the exercise heart rate (pulse/min) related to the respiratory rate?

As the respiratory rate returns to normal following exercise, what happens to the pulse rate?

How would you explain the correlation or lack thereof between the heart rate and the respiratory rate?

The table below shows some guidelines for the expected pulse rate 2 minutes after vigorous exercise in individuals of various physical conditions. (Speed of return relates to circulatory efficiency.)

<table>
<thead>
<tr>
<th>Physical Condition</th>
<th>Pulse Rate (Beats/minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>71-78</td>
</tr>
<tr>
<td>Very Good</td>
<td>79-83</td>
</tr>
<tr>
<td>Average</td>
<td>84-99</td>
</tr>
<tr>
<td>Below Average</td>
<td>100-107</td>
</tr>
<tr>
<td>Poor</td>
<td>108-118</td>
</tr>
<tr>
<td>Very Poor</td>
<td>Above 119</td>
</tr>
</tbody>
</table>

FINALLY, HAVE A HAPPY AND HEALTHY SUMMER.