Name _____ **Instructor** _____ **Lab Section**_____

Objectives: To gain an understanding of:

- What is meant by the term "physical fitness"
- Various tests used to measure an individual's level of physical fitness

Background material may be found in:

- Chapter: 22.1-22.2, 22.6-22.11
- Chapter: 23 (many sections)

Biology: Concepts & Connections, 8th ed.

What exactly do we mean when we say a person is physically fit? You'll recall that many of the activities required to sustain life (e.g. active transport, growth, movement) require energy. This energy is produced by the breakdown of food (carbohydrates, lipids, and proteins) through the process of respiration. The most efficient release of energy occurs in the presence of oxygen (**aerobic respiration**). However, unlike food, oxygen cannot be stored in the body. It must be constantly taken into the body and transported to all cells to sustain their activities.

Muscle cells used to produce movement during physical activity require large amounts of energy. As the need for energy increases with increased exertion, so does the need for oxygen in the muscle tissue.

Often during vigorous physical activity more oxygen is required by the muscles than the body can supply. In this case, the supply of oxygen is insufficient to produce all the energy needed by the muscles. Instead of just giving up, the muscles release energy from food molecules without oxygen, or **anaerobically**. However, this conversion is not very efficient, and soon the inadequate supply of energy along with the accumulation of anaerobic by-products (the primary one being lactic acid) results in fatigue. The more vigorous and prolonged the activity, the greater is the "**oxygen debt**" that develops, and the greater the stress on the heart, lungs, and muscles. Once the activity is over, the individual will continue to breathe rapidly for a time to provide the body with the oxygen that he or she was unable to acquire while active. The oxygen is used to convert the accumulated lactic acid into water and carbon dioxide. In this way one makes up or "pays back" the oxygen debt incurred during exercise.

Regular participation in physical activities results in changes in the heart, blood vessels, blood, and lungs, that are geared toward more efficiently supplying the body with oxygen (aerobic conditioning). Therefore, when we speak of physical fitness, we are considering **(1) how efficiently the lungs (respiratory system) can take oxygen into the body, (2) how efficiently the heart, blood, and blood vessels (cardiovascular system) can transport it to the muscles during times of physical stress,** and **(3) how rapidly the muscles can utilize the oxygen and food to release energy for contraction.**

The following tests are designed to measure your physical fitness or aerobic conditioning. Keep in mind the above idea of physical fitness and try to relate the design of each test to that concept.

RESPIRATORY CONDITION

One way of measuring the condition of your lungs is by measuring the maximum volume of air that can be exchanged with the atmosphere with each breath. This maximum volume is called **vital capacity**.

1. Set the respirometer at zero.

2. Insert a disposable mouthpiece into the respirometer.

3. Inhale as deeply as possible.

4. Then place your mouth to the tube and exhale fully into the apparatus.

5. The recording on the gauge is your vital capacity in liters. **Place your used mouthpiece in the designated container.**

6. Multiply this figure by **1000** to calculate your vital capacity in milliliters (ml). Record this figure below:

VITAL CAPACITY = _____ ML

7. To determine if your vital capacity is above or below average, first measure your height in centimeters by standing against the meter sticks placed near the door. Since there are two meter sticks stacked on top of each other, you will need to add 100 to the top measured number to get your height in cm:

HEIGHT = _____ CM

8. Now on your table find the vital capacity chart, and turn it to the correct side (male or female). On this chart find where your age and height (in cm) intersect. The number at this intersection is the average vital capacity for a person your age, sex, and height. Record this value below:
AVERAGE VITAL CAPACITY = _____ ML
(FOR A PERSON OF YOUR AGE, HEIGHT, AND SEX)

9. Compute your **percent of expected vital capacity**, using the following equation:

$$\frac{\text{YOUR VITAL CAPACITY}}{\text{AVERAGE VITAL CAPACITY (FOR A PERSON OF YOUR AGE, HEIGHT, AND SEX)}} \times 100 = \_\_\_\_\_\%$$

QUESTIONS

1. Whose vital capacities are typically larger, the males in the class or the females? Why? Does this mean they are any more or less "physically fit"?

2. If a person had a lower than average vital capacity, what are some things they could do to improve it?

3. Examine the "smoker's lung" on the front table. What effect would smoking and other lung diseases have upon vital capacity?

BLOOD-OXYGEN CARRYING CAPACITY: HEMATOCRIT

Almost all of the oxygen transported by the blood is carried by **red blood cells (RBCs or erythrocytes),** with only 1/70 of the oxygen being dissolved in the **plasma**. The ability of the RBCs to carry this large amount of oxygen to supply the needs of all the cells of the body depends upon the oxygen-carrying molecule called **hemoglobin (Hb),** which is found in high concentration within each RBC.

In response to a regular, vigorous program of aerobic conditioning, the body adapts by (1) increasing blood volume (more blood to carry more oxygen), and (2) increasing the number or concentration of RBCs per volume of blood (more RBCs = more hemoglobin per volume of blood to carry more oxygen).

The percentage of the volume of blood that consists of RBCs is referred to as the **hematocrit**. An average hematocrit of a person in good health is between 38-45% for females (38% to 45% of the total volume of blood consists of RBCs), and between 40-50% for males. A higher percentage may result from good conditioning, while a lower figure may indicate a state of **anemia**.

Hematocrit tends to rise in response to aerobic exercise, life at high altitudes, and exposure to carbon monoxide (a gas released by cigarettes and automobile exhausts), which inactivates hemoglobin and reduces its oxygen-carrying ability. Hematocrit tends to drop in response to inactivity, blood loss (ulcers, menstruation), and nutritional deficiencies (insufficient iron, protein, folic acid, or vitamin B-12).

1. Determine the hematocrits of the artificial "blood" samples on the front table, and enter your results on the table on the following page. For each tube, use a small ruler, to measure the distance (in cm) from the bottom of each tube to the top of the plasma (the clear portion), this is the **total volume of blood measurement**. Next, measure the distance (in cm) from the bottom of each tube to the top of the packed red blood cells (the red portion), this is the **red blood cell volume measurement**. Divide the distance for the red cell portion by the distance for the entire volume of blood to determine the hematocrit. (Note: while this is not strictly a volume measurement, since the radius of the tube and the total volume in each tube is constant, the hematocrits will still be correct).

2. Enter your results in the table below.

SAMPLE	TOTAL BLOOD VOLUME MEASUREMENT (cm)	RED BLOOD CELL VOLUME MEASUREMENT (cm)	HEMATOCRIT
A			
B			
C			

3. a. Which sample might have been taken from an anemic individual?

b. What factors can contribute to anemia that might be causing this person's low hematocrit levels?

4. What are some possible explanations for the high hematocrit seen in Sample C?

CARDIOVASCULAR CONDITION

HEART MODEL

Locate the parts of the human heart in the large model at the front of the lab (and on the diagram at the end of the lab). Note the two different paths or circuits that the blood takes as it circulates through the heart:

1. PULMONARY CIRCULATION

Blood which is relatively **low in oxygen (O_2) and high in carbon dioxide (CO_2) concentration** returning from the body is sent from the heart to the lungs through the **pulmonary arteries**. There, O_2 is taken up from and CO_2 is released to the alveoli of the lungs. This blood, which is now relatively **high in O_2 and low in CO_2 concentration** is transported back to the heart through the **pulmonary veins.**

NOTE: by definition, **arteries** are blood vessels that **carry blood away from the heart** while **veins** are blood vessels which **carry blood back to the heart**. Arteries do not necessarily carry well oxygenated blood (for example, the pulmonary arteries) and veins do not necessarily carry deoxygenated blood (for example, the pulmonary veins).

2. SYSTEMIC CIRCULATION

This oxygen-rich blood is then pumped from the heart to the rest of the body through the aorta and **systemic arteries**. The cells of the body use the oxygen contained in the blood (for aerobic cell respiration) and release carbon dioxide into the blood (a waste product of aerobic cell respiration). Thus the blood returning to the heart through the **systemic veins** and vena cava is again low in oxygen and high in carbon dioxide, completing the circuit.

HEART RATE

With regular physical activity the heart muscle becomes larger and stronger, permitting it to pump more blood with each beat. If the heart is capable of pumping more blood with each beat (**stroke volume**), it can:
1) supply more blood during exercise at maximum **heart rate** (around 200 beats per minute), and
2) it does not need to beat as fast to supply the body with blood at rest. Therefore the **resting heart rate** is an indicator of how strong your heart is, and also of your degree of fitness.

Feel for your pulse at the carotid artery in your neck or the radial artery in your forearm, (your instructor will demonstrate). Count the number of beats in 30 seconds, then multiply by 2 to get the resting heart rate in beats per minute. Record below:

RESTING HEART RATE (BEATS PER MINUTE) = _____

Compare with your lab partner and with other members of the class to see what resting heart rates are found.

QUESTIONS

1. Do resting heart rates correlate with the relative degree of physical fitness among the members of your lab?

2. What sort of resting heart rate would you expect to see in a lean, well-conditioned distance runner? In an inactive and overweight "couch potato"? Why?

3. The best time to measure resting heart rate is right when you wake up, before you have begun any daily activities. What factors, other than heart strength or physical fitness, might affect your heart rate?

ELECTROCARDIOGRAPHY (ECG OR EKG)

The electrocardiograph is a means of recording the waves of electrical changes that occur during a heart beat. It is extremely useful in detecting problems of a diseased heart before excessive damage has occurred. We will examine the normal EKG pattern first, and then your instructor will explain some of the abnormal patterns that indicate heart disease.

Nerve impulses and muscle contraction involve sudden changes in electric charge at the surface of the cell membrane. In normal resting cells, including both plant and animal cells, the outside of the cell membrane is electrically positive (+) while the inside of the cell is electrically negative (-). With this difference in charge across the cell membrane, the cell is **polarized** (it has a resting membrane potential).

When a nerve cell or muscle cell is stimulated, there is a rapid, local **depolarization** of the cell such that the inside of the cell becomes positive and the outside of the membrane momentarily becomes electrically negative. This momentary depolarization moves along the surface of the cell membrane as a self-propagating wave, triggering contraction of the muscle (an action potential). A fraction of a second later the cell membrane **repolarizes** (re-sets itself), which allows the muscle to relax.

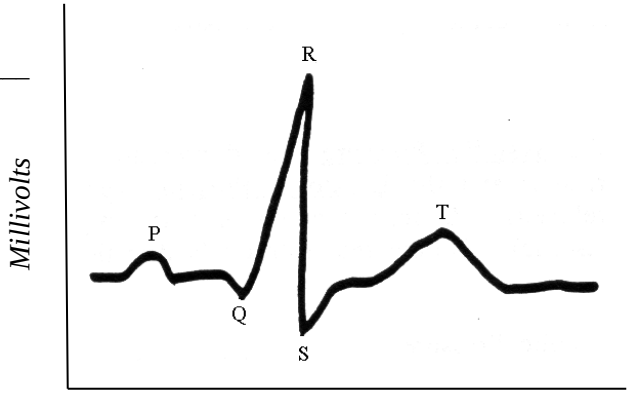
In the contraction of the heart, the impulse starts at the "**pacemaker" (the Sino-Atrial Node, or SA node)** in the wall of the right atrium. Both atria then depolarize and contract simultaneously. The EKG machine picks up this depolarization and records it as the **P wave**. The impulse then reaches the **Atrio-Ventricular Node (AV node),** located between the atria and the ventricles. The AV node delays the beat until the atria have finished contracting, then it relays the beat to the ventricles via a specialized bundle of fibers (**the AV bundle, or Bundle of His**). Depolarization of the ventricles produces the **QRS wave** on the electrocardiogram, and the ventricles contract. Finally, repolarization of the ventricles registers as the **T wave**, and the ventricles relax. This normal EKG pattern is shown on the next page.

QUESTION: In the following diagram of a typical EKG pattern, indicate what action produces the P wave, QRS wave, and T wave.

QRS wave: _____

P wave:

_____



T wave: _____

Milliseconds

Some of the cardiac problems indicated by abnormal EKG patterns are:

1. **abnormal heart rate** (tachycardia = heart beats too fast; bradycardia = heart beats too slow)
2. **unusual position of the heart** (axis deviation), perhaps due to enlargement of the heart as a result of arterial resistance & hypertension.
3. **reduced blood supply to part of the heart due to blocked coronary arteries** (atherosclerosis). this could be a warning of a possible "heart attack" (myocardial infarction) in the near future.
4. **blockage of transmission of impulses** between the sa and av nodes or in the bundle of his
5. **abnormal rhythms** arrhythmias due to the heart beat originating from unusual centers (ectopic foci).

BLOOD PRESSURE

Blood pressure is the amount of force that blood exerts against the walls of blood vessels. It is the product of:

1. CARDIAC OUTPUT (PULSE RATE X STROKE VOLUME)

2. RESISTANCE IN VESSELS (RESISTANCE TO THE FLOW OF BLOOD THROUGH THE BLOOD VESSELS)

A MORE PHYSICALLY FIT PERSON WILL USUALLY HAVE A LOWER BLOOD PRESSURE BECAUSE HE OR SHE WILL HAVE:

1. A **LOWER PULSE RATE**, DUE TO A HIGHER HEMATOCRIT AND LARGER STROKE VOLUME
2. A **REDUCED TOTAL PERIPHERAL RESISTANCE**, DUE TO THE BLOOD VESSELS BEING LARGER, MORE NUMEROUS, AND LESS OBSTRUCTED BY THE PLAQUE DEPOSITS WHICH ARE CHARACTERISTIC OF ATHEROSCLEROSIS.

You will measure the **systolic pressure** (blood pressure while the ventricles are contracted) and the **diastolic pressure** (pressure while the ventricles are relaxed). **A normal blood pressure might be 120 / 80 (Systolic / Diastolic).** Follow the instructor's directions to obtain your:

SYSTOLIC PRESSURE = _____

DIASTOLIC PRESSURE = _____

Elevated blood pressure is called **hypertension**, defined as a systolic pressure over 140 or a diastolic pressure over 90. Since hypertension and its consequences is the largest killer of Americans today, it makes good sense to take your blood pressure yearly, or more often, and to take steps to combat hypertension if you show elevated values.

AEROBIC CONDITION - A MEASURE OF YOUR OVERALL PHYSICAL FITNESS

Thus far we have considered the condition of the lungs, heart, and vascular system somewhat independently.

Based on the preceding information, predict the characteristics a physically fit individual (as compared to an unfit person) would have:

1. **Vital Capacity**

2. **Hematocrit**

3. **Resting Heart Rate**

4. **Blood Pressure**

In the following test we will integrate the condition of all of the above to give you an overall aerobic condition. A physically fit person will be able to supply his body with the oxygen it needs using fewer heart beats per unit time than a less fit individual. Therefore, the pulse rate of a person after a given exercise should be a good indication of his or her relative aerobic condition.

The procedure on the next page will give you a general idea of your overall level of physical fitness.

THE YMCA BENCH STEP TEST

The YMCA Bench Step Test is a standardized test to measure your aerobic condition (cardiovascular fitness). Using the following procedure you will be able to determine how efficiently your body can supply itself with the oxygen it needs during physical stress.

NOTE: IF you have a history of heart trouble or other illness for which physical exercise is not recommended, DO NOT PERFORM THIS EXERCISE!!!

1. Use a metronome to help you step at the correct rate, 96 steps per minute.

2. Set a stopwatch to 3 minutes. When you are ready to begin, start the stopwatch and begin stepping on and off the step, one foot at a time (e.g., left foot up, right foot up, left foot down, right foot down). **Maintain this exercise level for 3 minutes, or until exhaustion forces you to stop**.

3. **Immediately upon stopping exercise, find a place to sit and begin counting your pulse. Count the number of pulse beats for 60 seconds.**

4. After counting your pulse for 60 seconds, record your pulse rate and locate your score in the rating scale below.

- **Your Results: _____ beats/minute immediately following step test.**

- **According to this test, what is your physical condition (see table below)? _____**

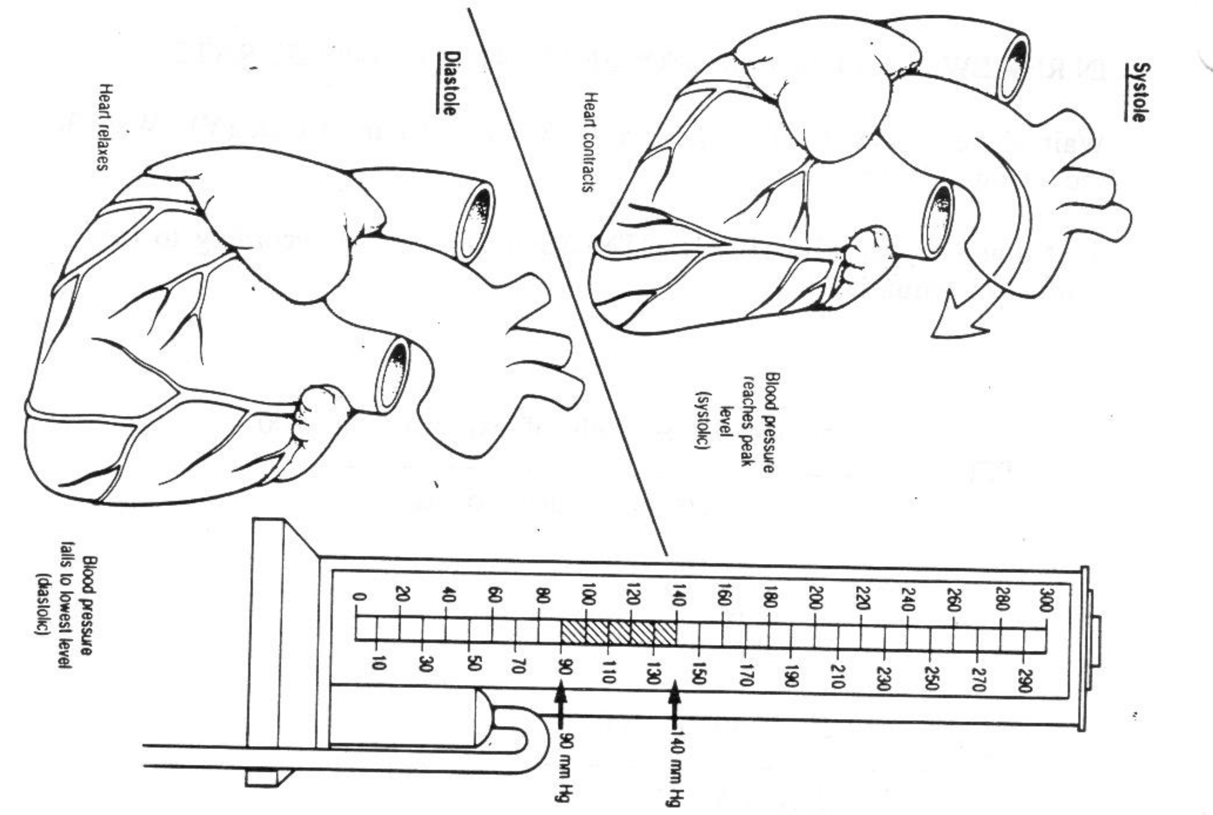
Age-adjusted standards based on guidelines published by YMCA.

Ratings for Women, Based on Age

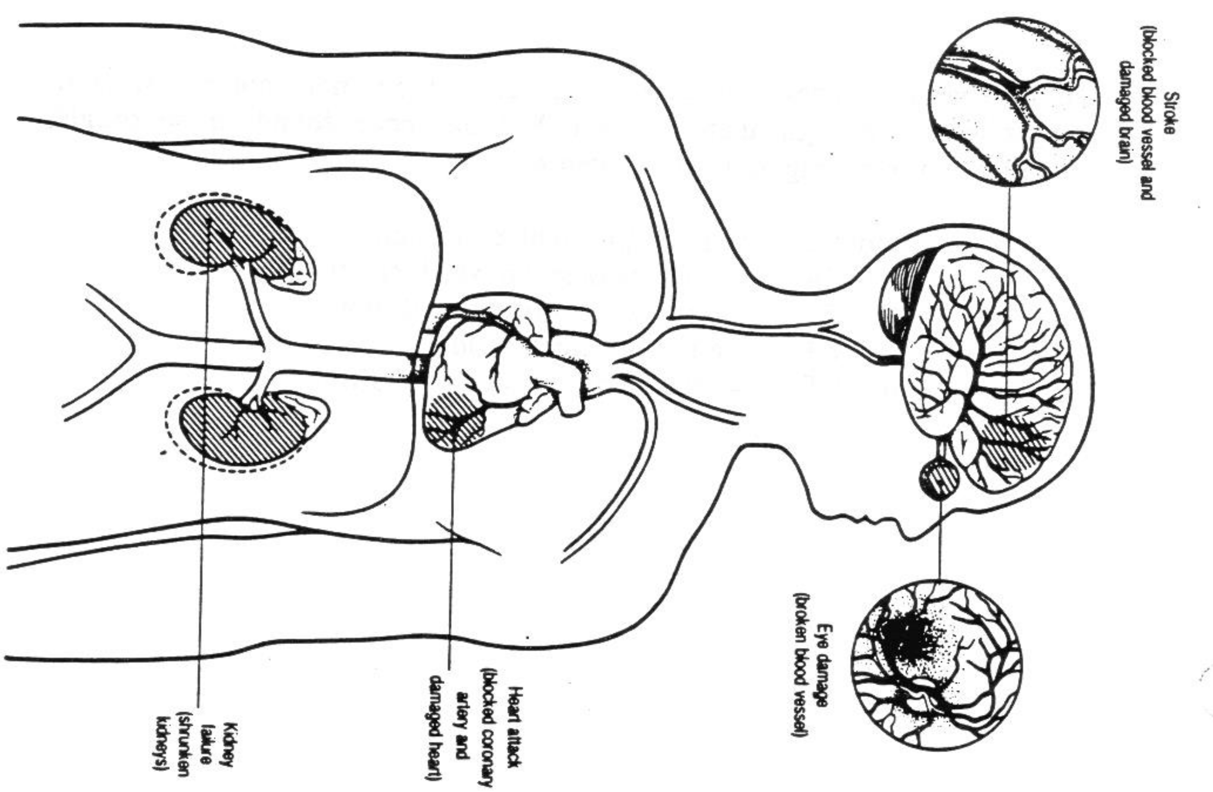
	18-25	26-35	36-45	46-55	56-65	65+
Excellent	52-81	58-80	51-84	63-91	60-92	70-92
Good	85-93	85-92	89-96	95-101	97-103	96-101
Above Average	96-102	95-101	100-104	104-110	106-111	104-111
Average	104-110	104-110	107-112	113-118	113-118	116-121
Below Average	113-120	113-119	115-120	120-124	119-127	123-126
Poor	122-131	122-129	124-132	126-132	129-135	128-133
Very Poor	135-169	134-171	137-169	137-171	141-174	135-155

Ratings for Men, Based on Age

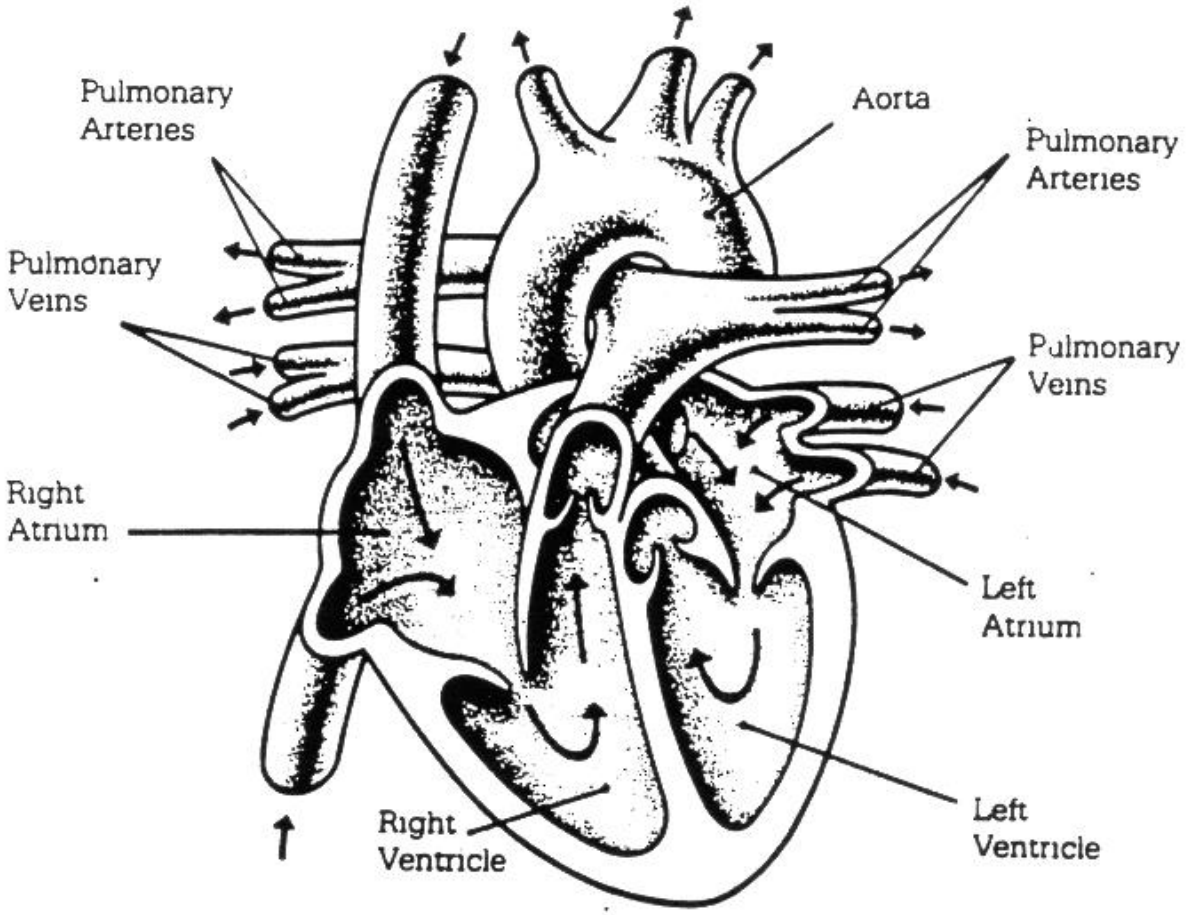
	18-25	26-35	36-45	46-55	56-65	65+
Excellent	50-76	51-76	49-76	56-82	60-77	59-81
Good	79-84	79-85	80-88	87-93	86-94	87-92
Above Average	88-93	88-94	92-88	95-101	97-100	94-102
Average	95-100	96-102	100-105	103-111	103-109	104-110
Below Average	102-107	104-110	108-113	113-119	111-117	114-118
Poor	111-119	114-121	116-124	121-126	119-128	121-126
Very Poor	124-157	126-161	130-163	131-159	131-154	130-151



SYSTOLIC AND DIASTOLIC PRESSURE



COMPLICATIONS OF HIGH BLOOD PRESSURE



The arrows show the direction of blood flow through the heart.

Clean-up:

_____ **Remove all air from blood pressure monitor and put neatly back in case. If it does not fit properly then all air has not been removed. Place on tray on your table.**

_____ **Place stethoscopes correctly in their boxes so that box will close. Place on tray on your table.**

_____ **Place calculators, unused alcohol wipes and rulers on tray on your table.**

_____ **Used alcohol wipes and EKG paper go into the trash.**

LABORATORY NOTES