exercise

22

Determinations

Any comprehensive study of cardiovascular physiology takes much more time than a single laboratory period. However, it is possible to investigate pulse, heart sounds, and blood pressure, all of which reflect the heart and blood vessels in action. The discussion of the cardiac cycle just below will help you to understand and interpret the physiological measurements taken during the lab.

Cardiac Cycle

Objective 1: Define *systole, diastole,* and *cardiac cycle,* and describe the events of the cardiac cycle.

In a healthy heart, the atria contract simultaneously. Then, as they begin to relax, the ventricles contract. However, in general usage, the terms **systole** and **diastole** refer to contraction and relaxation respectively of the ventricles.

The **cardiac cycle** includes events of one complete heartbeat, during which both atria and ventricles contract and then relax, and a predictable sequence of changes in blood volume and pressure occur within the heart. Figure 22.1 is a graphic representation of the events of the cardiac cycle for the left side of the heart. Pressure changes in the right side are less dramatic, but the same relationships apply.

Let's start our discussion of the cardiac cycle with the heart in complete relaxation (diastole). Pressure in the heart is very low, and blood is flowing passively from the pulmonary and systemic circulations into the atria and on through to the ventricles. The semilunar valves are closed, and the AV valves are open. Then atrial contraction occurs and atrial pressure increases, forcing blood remaining in their chambers into the ventricles. Then ventricular systole begins and pressure in the ventricles rises rapidly, closing the AV valves. When ventricular pressure exceeds that of the large arteries leaving the heart, the semilunar valves are forced open; and the blood in the ventricles gushes through those valves. During this phase, the pressure in the aorta reaches approximately 120 mm Hg. While the ventricles are contracting, the atria relax and as their chambers fill with blood, atrial pressure gradually rises. At the end of the ventricular systole, the ventricles relax; the semilunar valves snap shut, preventing backflow, and the pressure within the ventricles begins to drop. When intraventricular pressure is again less than atrial pressure, the AV valves are forced open; and the ventricles again begin to fill with blood. Atrial and aortic pressures decrease, and the ventricles rapidly refill, completing the cycle. The average heart beats approximately 72 to 75 beats per minute, and so the length of the cardiac cycle is about 0.8 second.

Study Figure 22.1 carefully to make sure you understand what has been discussed before continuing on with the exercise.

Before You Begin:

- Read the section on heart physiology and blood pressure regulation in your textbook.
- Brush up on blood vessel anatomy.
- Scan the exercise for the objectives you will be expected to accomplish during this laboratory session.

Materials

- ☐ Stethoscope
- ☐ Sphygmomanometer
- ☐ Watch (or clock) with a second hand
- ☐ Step stools (16 in. and 20 in. in height)
- ☐ Cot (if available)
- ☐ Alcohol swabs
- ☐ Record or audiotape: "Interpreting Heart Sounds" (available on free loan from the local chapters of the American Heart Association)
- ☐ Phonograph or tape deck
- ☐ Felt marker

Heart Sounds

Objective 2: Relate heart sounds to events of the cardiac cycle.

Two distinct sounds can be heard during each cardiac cycle. These **heart sounds** are commonly described by the monosyllables "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 close at the beginning of systole. The

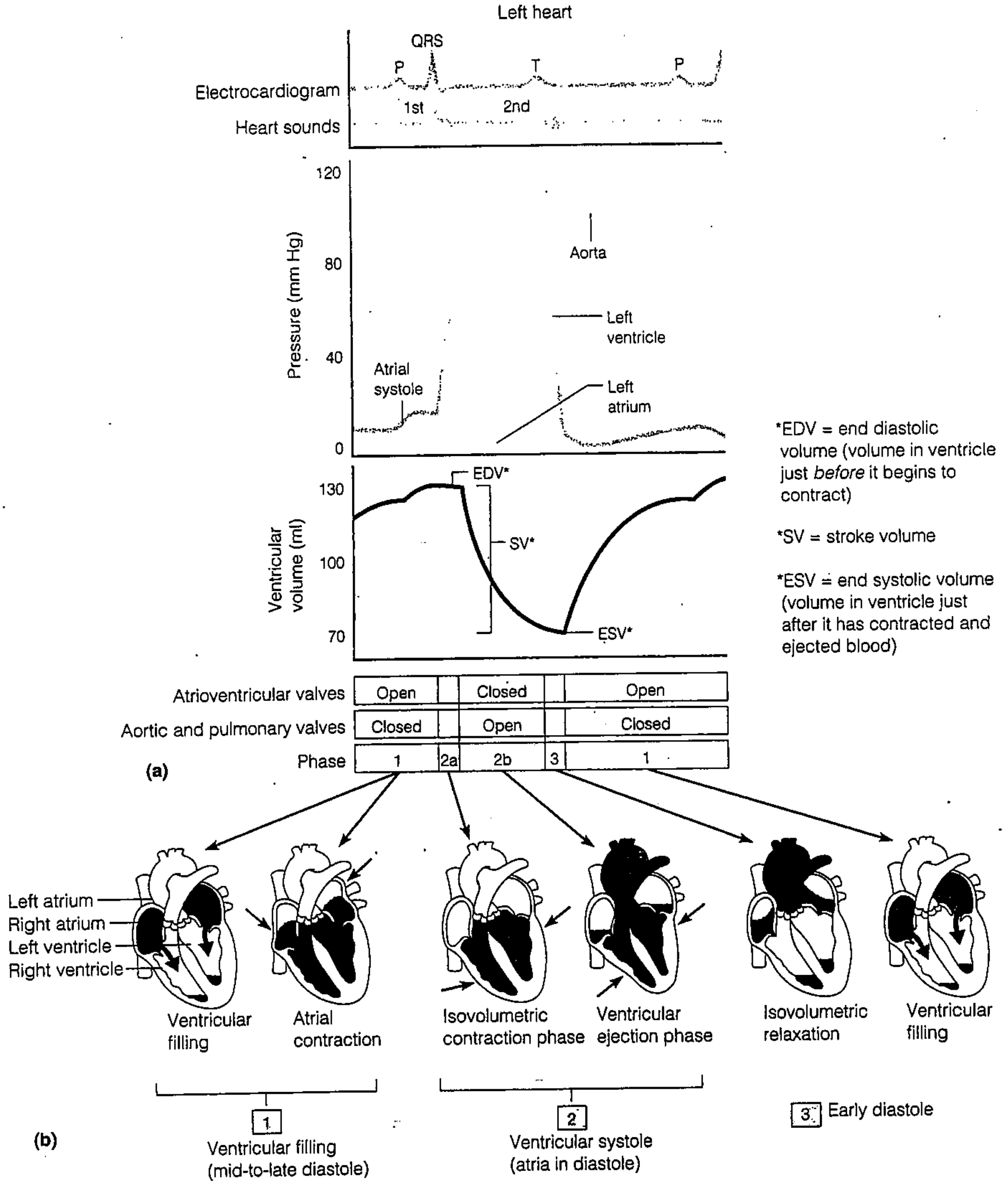

Figure 22.1 Summary of events occurring in the heart during the cardiac cycle. (a) Events in the left side of the heart. An electrocardiogram tracing is superimposed on the graph (top) so that pressure and volume changes can be related to electrical events occurring at any point. The P wave indicates depolarization of the atria; the QRS wave is depolarization of the ventricles; the T wave is repolarization of the ventricles (which hides the polarization wave of the atria). Time occurrence of heart sounds is also indicated. (b) Events of phases 1 through 3 of the cardiac cycle are depicted in diagrammatic views of the heart.

second heart string (dup) occurs as the semilunar valves close at the end of systole. Figure 22.1a indicates the timing of heart sounds in the cardiac cycle and in relation to an electrocardiogram.

Listen to the recording "Interpreting Heart Sounds" so that you may hear both normal and abnormal heart sounds. Abnormal heart sounds, called **murmurs**, often indicate valvular problems.

Activity:

Auscultating Heart Sounds

In the following procedure, you will auscultate (listen to) your partner's heart sounds with an ordinary stethoscope.

1. Obtain a stethoscope and some alcohol swabs. Heart sounds are best auscultated if the subject's outer clothing is removed, so a male subject is preferable.
2. Clean the earpieces of the stethoscope with an alcohol swab. Allow the alcohol to dry. Notice that the earpieces are angled. For comfort, the earpieces should be angled in a *forward* direction when you place them into your ears.
3. Don the stethoscope. Place the diaphragm of the stethoscope on your partner's thorax, just medial to the left nipple at the fifth intercostal space. Listen carefully for heart sounds. The first sound will be a longer, louder (more booming) sound than the second, which is short and sharp. After listening for a couple minutes, try to time the pause between the second sound of one heartbeat and the first sound of the subsequent heartbeat.

How long is this interval? ________________ sec

How does it compare to the interval between the first and second sounds of a single heartbeat?

____

____ ■

The Pulse

Objective 3: Define pulse and accurately determine a subject's radial and apical pulse.

The term **pulse** refers to the alternating surges of pressure (expansion and then recoil) in an artery that occur with each beat of the left ventricle. Normally the pulse rate equals the heart rate, and the pulse averages 70 to 76 beats per minute in the resting state.

Conditions other than pulse *rate* are also useful clinically. Can you feel it strongly—does the blood vessel expand and recoil (sometimes visibly) with the pressure waves—or is it difficult to detect? Is it regular like the ticking of a clock, or does it seem to skip beats?

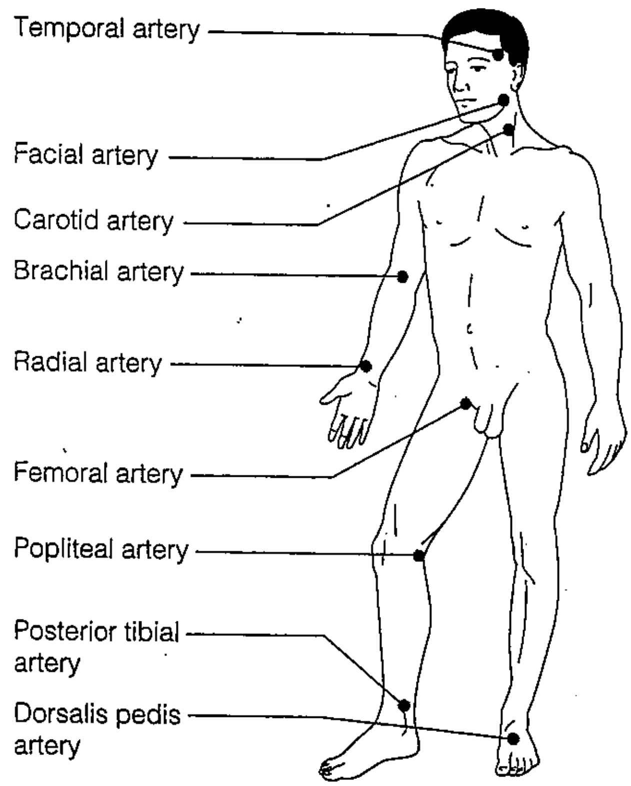

Figure 22.2 Body sites where the pulse is most easily palpated.

Activity:

Palpating Superficial Pulse Points

The pulse may be felt easily on any artery close to the body surface when the artery is compressed over a bone or firm tissue. Palpate the following pulse or pressure points on your partner by placing the fingertips of the first two or three fingers of one hand over the artery. It helps to compress the artery firmly as you begin your palpation and then immediately ease up on the pressure slightly. In each case, notice the regularity of the pulse, and assess its force. Figure 22.2 illustrates the superficial pulse points to be palpated.

Common carotid artery: At the side of the neck

Temporal artery: Anterior to the ear, in the temple region

Facial artery: Clench the teeth, and palpate the pulse just anterior to the masseter muscle in line with the corner of the mouth.

Brachial artery: In the antecubital fossa, at the point where it splits into the radial and ulnar arteries

Radial artery: At the lateral aspect of the wrist, just above the thumb

Femoral artery: In the groin

Popliteal artery: At the back of the knee

Posterior tibial artery: Just above the medial malleolus

Dorsalis pedis artery: On the dorsum of the foot

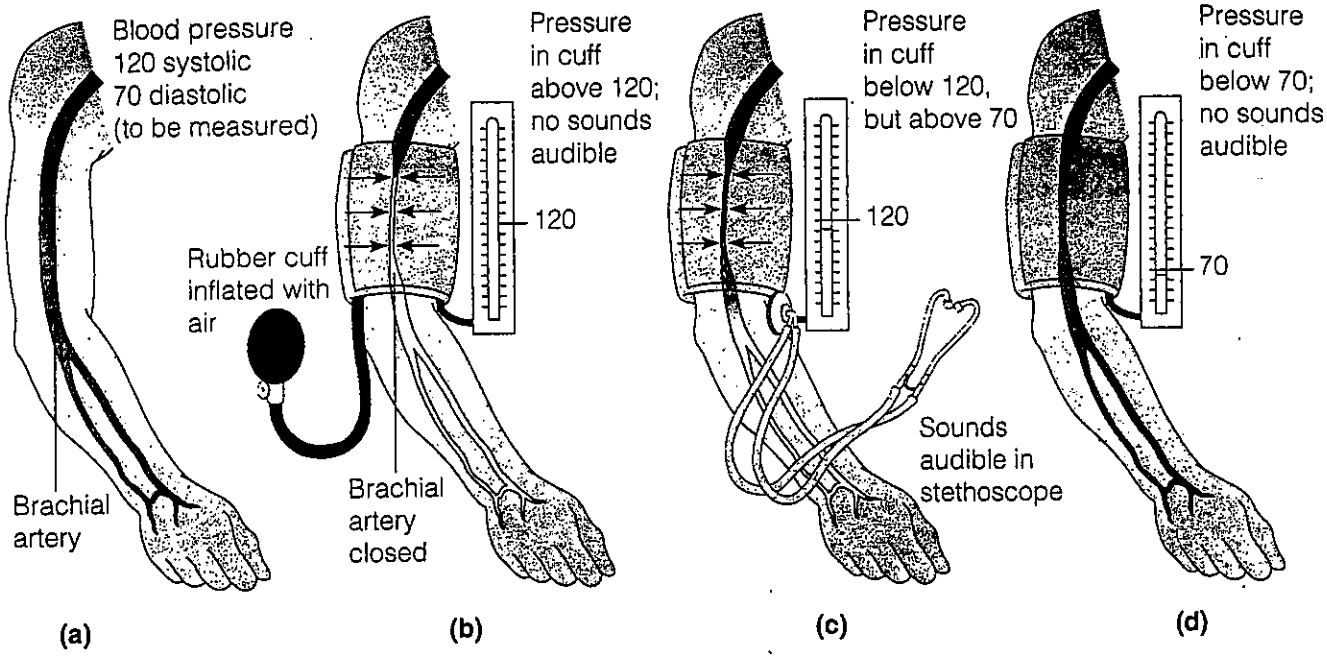

Figure 22.3 Procedure for measurement of blood pressure. (Assume a blood pressure of 120/70.)

Which pulse point had the greatest amplitude?

____

Which the least? ______________________________

Can you offer any explanation for this? ______________________________

____

____

____

Because of its easy accessibility, the pulse is most often taken on the radial artery. With your partner sitting quietly, practice counting the radial pulse for 1 minute. Make three counts and average the results.

count 1 ______________ count 2 ______________

count 3 ______________ average ______________ ■

Apical-Radial Pulse

The relationship between the apical and radial pulse rates can be determined by counting them simultaneously. The **apical pulse** (actually the counting of heartbeats) may be slightly faster than the radial because of a slight lag in time as the blood rushes from the heart into the large arteries where it can be palpated. However, any large difference between the values observed may indicate a weakened heart that is unable to pump sufficient blood into the arterial tree or abnormal heart rhythms. Apical pulse counts are routinely ordered for people with cardiac disease.

Activity:

Taking an Apical Pulse

With the subject sitting quietly, one student, using a stethoscope, should determine the apical pulse rate while another counts the radial pulse rate at the same time. The stethoscope should be positioned over the fifth left intercostal space. The person taking the radial pulse will determine the starting point for the count and give the stop-count signal exactly 1 minute later. Record your values below.

apical count ______________ beats/min

radial count ______________ pulses/min

pulse deficit ______________ /min ■

Blood Pressure Determinations

Objective 4: Define *blood pressure* and *pulse,* and accurately determine a subject's pulse with a sphygmomanometer.

Blood pressure is the pressure the blood exerts against the inner blood vessel walls; it is generally measured in the arteries. Because the heart alternately contracts and relaxes, the rhythmic flow of blood into the arteries causes the blood pressure to rise and fall during each beat. Thus you must take two blood pressure readings: the **systolic pressure,** which is the pressure in the arteries at the peak of ventricular ejection, and the **diastolic pressure,** the pressure during ventricular relaxation. Blood pressures are reported in millimeters of mercury (mm Hg), with the systolic pressure appearing first;

120/80 translates to 120 over 80, or a systolic pressure of 120 mm Hg and a diastolic pressure of 80 mm Hg. However, normal blood pressure varies considerably from one person to another.

Activity:

Using a Sphygmomanometer to Measure Arterial Blood Pressure Indirectly

The sphygmomanometer, commonly called a *blood pressure cuff*, is an instrument used to measure blood pressure by the ausculatory method (Figure 22.3). It consists of an inflatable cuff with an attached pressure gauge. The cuff is wrapped snugly around the arm just above the elbow (see Figure 22.3b) and inflated until the cuff pressure exceeds systolic pressure to stop blood flow to the forearm. As cuff pressure is gradually released, the examiner listens with a stethoscope over the brachial artery (Figure 22.3c) for characteristic sounds called the **sounds of Korotkoff,** which indicate the resumption of blood flow into the forearm. The pressure at which the first soft tapping sounds are heard is recorded as the systolic pressure. As the pressure is reduced further, blood flow becomes more turbulent, and the sounds become louder. Below the diastolic pressure, when the artery is no longer compressed, blood flows freely and the sounds of Korotkoff can no longer be heard. The pressure at which the sounds disappear is recorded as the diastolic pressure (Figure 22.3d).

1. Work in pairs to obtain radial artery blood pressure readings. Obtain a stethoscope, alcohol swabs, and a sphygmomanometer. Clean the earpieces of the stethoscope with the alcohol swabs, and check the cuff for the presence of trapped air by compressing it against the laboratory table. (A partially inflated cuff will produce erroneous measurements.)

2. The subject should sit in a comfortable position with one arm resting on the laboratory table (approximately at heart level if possible). Wrap the cuff around the subject's arm, just above the elbow, with the inflatable area on the medial arm surface. The cuff may be marked with an arrow; if so, the arrow should be positioned over the brachial artery (Figure 22.3). Secure the cuff by tucking the distal end under the wrapped portion or by bringing the Velcro areas together.

3. Palpate the brachial pulse, and lightly mark its position with a felt pen. Don the stethoscope, and place its diaphragm over the pulse point.

⚠ <u>*The cuff should not be kept inflated for more than 1 minute.*</u> If you have any trouble obtaining a reading within this time, deflate the cuff, wait 1 or 2 minutes, and try again. (A prolonged interruption of blood flow can cause fainting.)

4. Inflate the cuff to approximately 160 mm Hg pressure, and slowly release the pressure valve. Watch the pressure gauge as you listen for the first soft thudding sounds of the blood spurting through the partially blocked artery. Make a mental note of this pressure (systolic pressure), and continue to release the cuff pressure. You will notice first an increase, then a muffling, of the sound. Record as the diastolic pressure, the pressure at which the sound disappears. Make two blood pressure determinations, and record your results below.

First trial:	Second trial:
systolic pressure ______	systolic pressure ______
diastolic pressure ______	diastolic pressure ______ ■

Activity:

Observing the Effect of Various Factors on Blood Pressure and Heart Rate

Arterial blood pressure is directly proportional to cardiac output (amount of blood pumped out of the left ventricle per minute) and peripheral resistance, that is,

$$BP = CO \times PR$$

Peripheral resistance is increased by constriction of blood vessels (most importantly the arterioles), by an increase in blood viscosity or volume, and by a loss of elasticity of the arteries (seen in arteriosclerosis). Any factor that increases either the cardiac output or the peripheral resistance causes an almost immediate reflex rise in blood pressure. The influence of two factors that alter blood pressure—posture and exercise—are investigated here.

To do the following tests efficiently, one student should act as the subject and two as examiners (one taking the radial pulse and the other ausculating the brachial blood pressure). A fourth student collects and records the data. The sphygmomanometer cuff should be left on the subject's arm throughout the experiments (in a deflated state, of course) so that, at the proper times, the blood pressure can be taken quickly. In each case, take the measurements at least twice.

Posture

To monitor circulatory adjustments to changes in position, take blood pressure and pulse measurements under the conditions noted in Chart 1. Also record your results on that chart.

Exercise

Objective 5: Investigate the effects of exercise on blood pressure, pulse, and cardiovascular fitness.

Changes in blood pressure and pulse during and after exercise provide a good yardstick for measuring overall cardiovascular fitness. Although there are more accurate tests to evaluate fitness, the *Harvard Step Test* described here is a quick way to compare the relative fitness level of a group of people.

You will be working in groups of four, duties assigned as indicated above, except that student 4, in addition to recording the data, will act as the timer and call the cadence (rhythm).

⚠ Any student with a known heart problem should refuse to be the subject.

All four students may act as the subject in turn, if desired, but the bench stepping is to be performed *at least twice* in each group—once with a well-conditioned person acting as the subject, and once with a poorly conditioned subject.

Chart 1 Cardiovascular Responses to Changes in Posture

	Trial 1		Trial 2	
	BP	Pulse	BP	Pulse
Sitting quietly	______	______	______	______
Reclining (after 2 to 3 min)	______	______	______	______
Immediately on standing from the reclining position ("at attention" stance)	______	______	______	______
After standing for 3 min	______	______	______	______

Bench stepping is the following series of movements repeated sequentially:

1. Place one foot on the step.
2. Step up with the other foot so that both feet are on the platform. Straighten the legs and the back.
3. Step down with the other foot.
4. Bring the other foot down.

The pace for the stepping will be set by the "timer" (student 4), who will repeat "Up-2-3-4, up-2-3-4" at such a pace that each "up-2-3-4" sequence takes 2 sec (so there are 30 cycles/min).

1. Student 4 should obtain the step (20-in. height for male subject, or 16 in. for a female subject) while baseline measurements are being obtained on the subject.
2. Once the baseline pulse and blood pressure measurements have been recorded on Chart 2, the subject is to stand quietly at attention for 2 min to allow his or her blood pressure to stabilize before beginning to step.
3. The subject is to bench step for as long as possible, up to a maximum of 5 min, according to the cadence called by the timer. Watch the subject for crouching (posture must remain erect). If he or she is unable to keep the pace up for 15 sec, stop the test.
4. When the subject is stopped by the pacer, stops voluntarily because he or she is unable to continue, or has completed 5 min of bench stepping, he or she is to sit down. At this point, record the duration of exercise (in seconds), and measure the blood pressure and pulse immediately and thereafter at 1-min intervals for 3 min post-exercise.
5. The subject's *index of physical fitness* is to be calculated using the following formula:

$$\text{Index} = \frac{\text{duration of exercise in seconds} \times 100}{2 \times \text{sum of the 3 pulse counts in recovery}}$$

Scores are interpreted according to the following scale:

below 55	poor physical condition
55 to 62	low average
63 to 71	average
72 to 79	high average
80 to 89	good
90 and over	excellent

6. Record the test values on Chart 2, and repeat the testing and recording procedure with the second subject.

When did you notice a greater elevation of blood pressure and pulse?

____

Explain: ______________________________

____

Was there a sizeable difference between the after-exercise values for well-conditioned and poorly conditioned individuals?

______________ Explain: ______________________________

______________________________ ■

Skin Color as an Indicator of Local Circulatory Dynamics

Skin color reveals with surprising accuracy the state of the local circulation. The experiments on local circulation outlined below consider a number of factors that affect blood flow to the tissues.

A good clinical diagnosis often depends on good observation skills and logical interpretation of the findings. A single example is given to demonstrate this: A massive hemorrhage may be internal and hidden (thus, not obvious), but will

Chart 2 Cardiovascular Responses to Changes in Exercise

Baseline: 5 min at 30/min	Baseline		Interval Following Test: Immediately		1 min		2 min		3 min	
	BP	P	BP	P	BP	P	BP	P	BP	P
Well-conditioned individual	____	____	____	____	____	____	____	____	____	____
Poorly conditioned individual	____	____	____	____	____	____	____	____	____	____

still threaten the blood delivery to vital organs. One of the earliest responses of the body to such a threat is constriction of the skin's blood vessels, which reduces blood flow to the skin and diverts it into the circulatory mainstream to serve other, more vital tissues. As a result, the skin, particularly that of the extremities, becomes pale, cold, and eventually moist with perspiration. Therefore, pale, cold, clammy skin should immediately lead the careful diagnostician to suspect that the circulation is dangerously inadequate.

Objective 6: Indicate factors affecting or determining blood flow and skin color.

Activity:

Examining the Effect of Local Chemical and Physical Factors on Skin Color

The local blood supply to the skin (indeed, to any tissue) is influenced by (1) local metabolites, (2) the oxygen supply, (3) local temperature, and (4) substances released by injured tissues, to name a few. Three of these factors are examined in the simple experiments that follow. Each experiment should be conducted by students in groups of three or four. One student will act as the subject; the others will conduct the tests and make and record observations.

Vasodilation and Flushing of the Skin Due to Lack of Oxygen

1. Obtain a blood pressure cuff (sphygmomanometer) and stethoscope. You will also need a watch with a second hand.

2. The subject should roll up the sleeves as high as possible and then lay the forearms side by side on the bench top.

3. Observe the general color of the subject's forearm skin, and the normal contour and size of the veins. Notice whether skin color is similar bilaterally. Record your observations:

____

____

____

4. Apply the blood pressure cuff to one arm, and inflate it to 250 mm Hg. Keep it inflated for 1 min. During this period, repeat the observations made above and record the results:

____

____

5. Release the pressure in the cuff (leaving the deflated cuff in position), and again record the forearm skin color and the condition of the forearm veins. Make this observation immediately after deflating and then again 30 sec later.

Immediately after deflating ______________________

____

30 sec after deflating ______________________

____

The above observations constitute your baseline information. Now conduct the following tests.

6. Instruct the subject to raise the cuffed arm above his or her head and to clench the fist as tightly as possible. While the hand and forearm muscles are tightly contracted, rapidly inflate the cuff to 240 mm Hg or more. This maneuver partially empties the hand and forearm of blood, and stops most blood flow to the hand and forearm. Once the cuff has been inflated, the subject is to relax the fist and return the forearm to the bench top so it can be compared to the other forearm.

7. Leave the cuff inflated for exactly 1 min. During this interval, compare the skin color in the "ischemic" (blood-deprived) hand to that of the "normal" (non-cuffed-limb) hand. After 1 min, quickly release the pressure.

What are the subjective effects* of stopping blood flow to the arm and hand for 1 min?

____

____

What are the objective effects (actual color of skin and condition of veins)?

____

____

How long does it take for the subject's ischemic hand to regain its normal color?

____

Effects of Venous Congestion

1. Again, but with a different subject, observe and record the appearance of the skin and veins on the forearms resting on the bench top. This time, pay particular attention to the color of the fingers, particularly the fingertips and the nail beds. Record this information:

____

____

2. Wrap the blood pressure cuff around one of the subject's arms, and inflate it to 40 mm Hg. Maintain this pressure for 5 min. Record the subjective and objective findings just before the 5 min are up, and then again immediately after release of the pressure at the end of 5 min.

Subjective (arm cuffed) ______________________________

____

Objective (arm cuffed) ______________________________

____

*Subjective effects are sensations—such as pain, coldness, warmth, tingling, and weakness—experienced by the subject. They are "symptoms" of a change in function.

Subjective (pressure released) ______________________________

____

Objective (pressure released) ______________________________

____

3. With still another subject, conduct the following simple experiment: Raise one arm above the head, and let the other hang by the side for 1 min. After 1 min, quickly lay both arms on the bench top, and compare their color.

Color of raised arm ______________________________

Color of dependent arm ______________________________

From this and the two preceding observations, analyze the factors that determine tint of color (pink or blue) and intensity of skin color (deep pink or blue as opposed to light pink or blue). Record your conclusions.

____

____

____

____

____

Effect of Mechanical Stimulation of Blood Vessels of the Skin

With moderate pressure, draw the blunt end of your pen across the skin of a subject's forearm. Wait 3 min to observe the effects, and then repeat with firmer pressure.

What changes in skin color do you observe with light-to-moderate pressure?

____

With heavy pressure? ______________________________

The redness, or *flare,* observed after mechanical stimulation of the skin results from a local inflammatory response promoted by *chemical mediators* released by injured tissues. These mediators stimulate increased blood flow into the area and cause the capillaries to leak fluid into the local tissues. (Note: People differ considerably in skin sensitivity. Those most sensitive will show **dermographism,** a condition in which the direct line of stimulation will swell quite obviously. This excessively swollen area is called a *wheal.*) ■