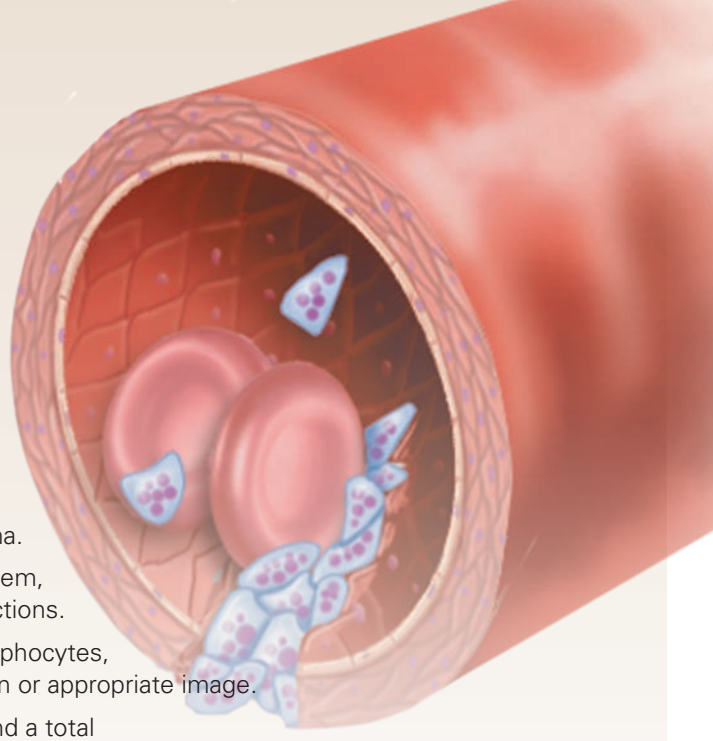
EXERCISE

29 Blood



Objectives

- ☐ Name the two major components of blood, and state their average percentages in whole blood.
- ☐ Describe the composition and functional importance of plasma.
- ☐ Define *formed elements,* and list the cell types composing them, state their relative percentages, and describe their major functions.
- ☐ Identify erythrocytes, basophils, eosinophils, monocytes, lymphocytes, and neutrophils when provided with a microscopic preparation or appropriate image.
- ☐ Provide the normal values for a total white blood cell count and a total red blood cell count, and state the importance of these tests.
- ☐ Conduct the following blood tests in the laboratory, and state their norms and the importance of each: differential white blood cell count, hematocrit, hemoglobin determination, clotting time, and plasma cholesterol concentration.
- ☐ Define *leukocytosis, leukopenia, leukemia, polycythemia,* and *anemia;* cite a possible cause for each condition.
- ☐ Perform an ABO and Rh blood typing test in the laboratory, and discuss the reason for transfusion reactions resulting from the administration of mismatched blood.

Materials

General supply area:

- Disposable gloves
- Safety glasses (student-provided)
- Bucket or large beaker containing 10% household bleach solution for slide and glassware disposal
- Spray bottles containing 10% bleach solution
- Autoclave bag
- Designated lancet (sharps) disposal container

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Pre-Lab Quiz

1. Circle True or False. There are no special precautions that I need to observe when performing today's lab.
2. Three types of formed elements found in blood include erythrocytes, leukocytes, and:
   a. electrolytes **b.** fibers **c.** platelets **d.** sodium salts
3. Circle the correct underlined term. Mature erythrocytes / leukocytes are the most numerous blood cells and do not have a nucleus.
4. The least numerous but largest of all agranulocytes is the:
   a. basophil **b.** lymphocyte **c.** monocyte **d.** neutrophil
5. _____ are the leukocytes responsible for releasing histamine and other mediators of inflammation.
   a. Basophils **b.** Eosinophils **c.** Monocytes **d.** Neutrophils
6. _____ are essential for blood clotting.
7. Circle the correct underlined term. When determining the hematocrit / hemoglobin, you will centrifuge whole blood in order to allow the formed elements to sink to the bottom of the sample.
8. Circle the correct underlined term. The normal hematocrit value for females / males is generally higher than that of the opposite sex.
9. Circle the correct underlined term. Blood typing is based on the presence of proteins known as antigens / antibodies on the outer surface of the red blood cell plasma membrane.
10. Circle True or False. If an individual is transfused with the wrong blood type, the recipient's antibodies react with the donor's blood antigens, eventually clumping and hemolyzing the donated RBCs.

- Plasma (obtained from an animal hospital or prepared by centrifuging animal [for example, cattle or sheep] blood obtained from a biological supply house)
- Test tubes and test tube racks
- Wide-range pH paper
- Stained smears of human blood from a biological supply house or, if desired by the instructor, heparinized animal blood obtained from a biological supply house or an animal hospital (for example, dog blood), or EDTA-treated red cells (reference cells*) with blood type labels obscured (available from Immucor, Inc.)

Note to the Instructor: *See directions below for handling of soiled glassware and disposable items.*

**The blood in these kits (each containing four blood cell types—A1, A2, B, and O—individually supplied in 10-ml vials) is used to calibrate cell counters and other automated clinical laboratory equipment. This blood has been carefully screened and can be safely used by students for blood typing and determining hematocrits. It is not usable for hemoglobin determinations or coagulation studies.*

- Clean microscope slides
- Glass stirring rods
- Wright's stain in a dropper bottle
- Distilled water in a dropper bottle
- Sterile lancets
- Absorbent cotton balls
- Alcohol swabs (wipes)
- Paper towels
- Compound microscope
- Immersion oil
- Assorted slides of white blood count pathologies labeled "Unknown Sample _____"
- Timer

Because many blood tests are to be conducted in this exercise, it is advisable to set up a number of appropriately labeled supply areas for the various tests, as designated below. Some needed supplies are located in the general supply area.

Note: *Artificial blood prepared by Ward's Natural Science can be used for differential counts, hematocrit, and blood typing.*

Activity 4: Hematocrit

- Heparinized capillary tubes
- Microhematocrit centrifuge and reading gauge (if the reading gauge is not available, a millimeter ruler may be used)
- Capillary tube sealer or modeling clay

Activity 5: Hemoglobin determination

- Hemoglobinometer, hemolysis applicator, and lens paper; or Tallquist hemoglobin scale and test paper

Activity 6: Coagulation time

- Capillary tubes (nonheparinized)
- Fine triangular file

Activity 7: Blood typing

- Blood typing sera (anti-A, anti-B, and anti-Rh [anti-D])
- Rh typing box
- Wax marking pencil
- Toothpicks
- Medicine dropper
- Blood test cards or microscope slides

Activity 8: Demonstration

- Microscopes set up with prepared slides demonstrating the following bone (or bone marrow) conditions: macrocytic hypochromic anemia, microcytic hypochromic anemia, sickle cell anemia, lymphocytic leukemia (chronic), and eosinophilia

Activity 9: Cholesterol measurement

- Cholesterol test cards and color scale

PEx PhysioEx™ 9.1 Computer Simulation Ex. 11 on p. PEx-161.

In this exercise, you will study plasma and formed elements of blood and conduct various hematologic tests. These tests are useful diagnostic tools for the physician because blood composition (number and types of blood cells, and chemical composition) reflects the status of many body functions and malfunctions.

ALERT: Special precautions when handling blood. This exercise provides information on blood from several sources: human, animal, human treated, and artificial blood. The instructor will decide whether to use animal blood for testing or to have students test their own blood in accordance with the educational goals of the student group. For example, for students in the nursing or laboratory technician curricula, learning how to safely handle human blood or other human wastes is essential. Whenever blood is being handled, special attention must be paid to safety precautions. Instructors who opt to use human blood are responsible for its safe handling. Precautions should be used regardless of the source of the blood. This will both teach good technique and ensure the safety of the students.

Follow exactly the safety precautions listed below.

1. Wear safety gloves at all times. Discard appropriately.
2. Wear safety glasses throughout the exercise.
3. Handle only your own, freshly drawn (human) blood.
4. Be sure you understand the instructions and have all supplies on hand before you begin any part of the exercise.
5. Do not reuse supplies and equipment once they have been exposed to blood.
6. Keep the lab area clean. Do not let anything that has come in contact with blood touch surfaces or other individuals in the lab. Keep track of the location of any supplies and equipment that come into contact with blood.
7. Immediately after use dispose of lancets in a designated disposal container. Do not put them down on the lab bench, even temporarily.
8. Dispose of all used cotton balls, alcohol swabs, blotting paper, and so forth, in autoclave bags; place all soiled glassware in containers of 10% bleach solution.
9. Wipe down the lab bench with 10% bleach solution when you finish.

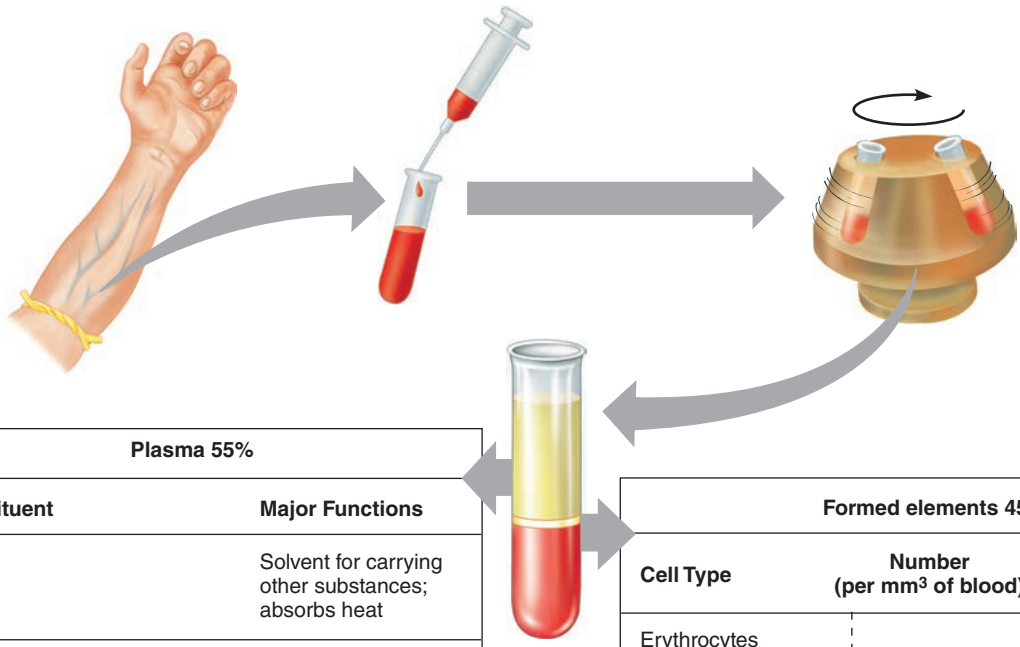
Composition of Blood

Circulating blood is a rather viscous substance that varies from bright red to a dull brick red, depending on the amount of oxygen it is carrying. Oxygen-rich blood is bright red. The average volume of blood in the body is about 5–6 L in adult males and 4–5 L in adult females.

Blood is classified as a type of connective tissue because it consists of a nonliving fluid matrix (the **plasma**) in which living cells (**formed elements**) are suspended. The fibers typical of a connective tissue matrix become visible in blood only when clotting occurs. They then appear as fibrin threads, which form the structural basis for clot formation.

More than 100 different substances are dissolved or suspended in plasma (**Figure 29.1**), which is over 90% water. These include nutrients, gases, hormones, various wastes and metabolites, many types of proteins, and electrolytes. The composition of plasma varies continuously as cells remove or add substances to the blood.

Three types of formed elements are present in blood (**Table 29.1**, p. 428). Most numerous are **erythrocytes,** or **red blood cells (RBCs),** which are literally sacs of hemoglobin molecules that transport the bulk of the oxygen carried in the blood (and a small percentage of the carbon dioxide). **Leukocytes,** or **white blood cells (WBCs),** are part of the body's nonspecific defenses and the immune system, and **platelets** function in hemostasis (blood clot formation); together they make up <1% of whole blood. Formed elements normally constitute about 45% of whole blood; plasma accounts for the remaining 55%.



Plasma 55%

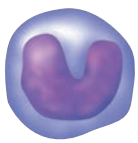
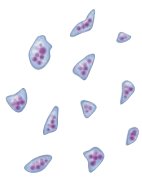
Constituent	Major Functions
Water	Solvent for carrying other substances; absorbs heat
Salts (electrolytes) Sodium Potassium Calcium Magnesium Chloride Bicarbonate	Osmotic balance, pH buffering
Plasma proteins Albumin Fibrinogen Globulins	 Osmotic balance Clotting of blood Defense (antibodies) and lipid transport
Substances transported by blood Nutrients (glucose, fatty acids, amino acids, vitamins) Waste products of metabolism (urea, uric acid) Respiratory gases (O_2 and CO_2) Hormones	

Formed elements 45%

Cell Type	Number (per mm^3 of blood)	Functions
Erythrocytes (red blood cells)	4 – 6 million	Transport oxygen and help transport carbon dioxide
Leukocytes (white blood cells)	4800 – 10,800	Defense and immunity
Basophil		
Eosinophil		
Neutrophil		
Lymphocyte		
Monocyte		
Platelets	150,000 – 400,000	Blood clotting

Figure 29.1 The composition of blood. Note that leukocytes and platelets are found in the band between plasma (above) and erythrocytes (below).

Table 29.1 Summary of Formed Elements of Blood

Cell type	Illustration	Description*	Cells/mm³ (µl) of blood	Function
Erythrocytes (red blood cells, RBCs)		Biconcave, anucleate disc; orange-pink color; diameter 7–8 µm	4–6 million	Transport oxygen and carbon dioxide
Leukocytes (white blood cells, WBCs)		Spherical, nucleated cells	4800–10,800	
Granulocytes Neutrophil		Nucleus multilobed; pale red and blue cytoplasmic granules; diameter 10–12 µm	3000–7000 Differential count: 50–70%	Phagocytize pathogens or debris
Eosinophil		Nucleus bilobed; red cytoplasmic granules; diameter 10–14 µm	100–400 Differential count: 2–4%	Kill parasitic worms; slightly phagocytic; complex role in allergy and asthma
Basophil		Nucleus lobed; large blue-purple cytoplasmic granules; diameter 10–14 µm	20–50 Differential count: <1%	Release histamine and other mediators of inflammation; contain heparin, an anticoagulant
Agranulocytes Lymphocyte		Nucleus spherical or indented; pale blue cytoplasm; diameter 5–17 µm	1500–3000 Differential count: 20–40%	Mount immune response by direct cell attack or via antibody production
Monocyte		Nucleus U- or kidney-shaped; gray-blue cytoplasm; diameter 14–24 µm	100–700 Differential count: 3–8%	Develop into macrophages in tissues and phagocytize pathogens or debris
Platelets		Cytoplasmic fragments containing granules; stain deep purple; diameter 2–4 µm	150,000–400,000	Seal small tears in blood vessels; instrumental in blood clotting

*Appearance when stained with Wright's stain.

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Activity 1

Determining the Physical Characteristics of Plasma

Go to the general supply area and carefully pour a few milliliters of plasma into a test tube. Also obtain some wide-range pH paper, and then return to your laboratory bench to make the following simple observations.

pH of Plasma

Test the pH of the plasma with wide-range pH paper.

Record the pH observed. _____

Color and Clarity of Plasma

Hold the test tube up to a source of natural light. Note and record its color and degree of transparency. Is it clear, translucent, or opaque?

Color _____

Degree of transparency _____

Consistency

While wearing gloves, dip your finger and thumb into plasma, and then press them firmly together for a few seconds. Gently pull them apart. How would you describe the consistency of plasma (slippery, watery, sticky, granular)? Record your observations.

_____

Activity 2

Examining the Formed Elements of Blood Microscopically

In this section, you will observe blood cells on an already prepared (purchased) blood slide or on a slide prepared from your own blood or blood provided by your instructor.

- If you are using the purchased blood slide, obtain a slide and begin your observations at step 6.
- If you are testing blood provided by a biological supply source or an animal hospital, obtain a tube of the supplied blood, disposable gloves, and the supplies listed in step 1, except for the lancets and alcohol swabs. After donning gloves, go to step 3b to begin your observations.
- If you are examining your own blood, you will perform all the steps described below *except* step 3b.

1. Obtain two glass slides, a glass stirring rod, dropper bottles of Wright's stain and distilled water, two or three lancets, cotton balls, and alcohol swabs. Bring this equipment to the laboratory bench. Clean the slides thoroughly and dry them.

2. Open the alcohol swab packet, and scrub your third or fourth finger with the swab. (Because the pricked finger may be a little sore later, it is better to prepare a finger on the nondominant hand.) Swing your hand in a cone-shaped path for 10 to 15 seconds. This will dry the alcohol and cause your fingers to become filled with blood. Then, open the lancet packet and grasp the lancet by its blunt end. Quickly jab the pointed end into the prepared finger to produce a free flow of blood. It is *not* a good idea to squeeze or "milk" the finger, because this forces out tissue fluid as well as blood. If the blood is not flowing freely, make another puncture.

⚠ *Under no circumstances is a lancet to be used for more than one puncture.* Dispose of the lancets in the designated disposal container immediately after use.

3a. With a cotton ball, wipe away the first drop of blood; then allow another large drop of blood to form. Touch the blood to one of the cleaned slides approximately 1.3 cm, or ½ inch, from the end. Then quickly (to prevent clotting) use the second slide to form a blood smear (**Figure 29.2**). When properly prepared, the blood smear is uniformly thin. If the blood smear appears streaked, the blood probably began to clot or coagulate before the smear was made, and another slide should be prepared. Continue at step 4.

3b. Dip a glass rod in the blood provided, and transfer a generous drop of blood to the end of a cleaned microscope slide. For the time being, lay the glass rod on a paper towel on the bench. Then, as described in step 3a (Figure 29.2), use the second slide to make your blood smear.

4. Allow the blood smear slide to air dry. When it is completely dry, it will look dull. Place it on a paper towel, and add 5 to 10 drops of Wright's stain. Count the number of drops of stain used. Allow the stain to remain on the slide for 3 to 4 minutes, and then add an equal number of drops of distilled water. Allow the water and Wright's stain mixture to remain on the slide for 4 or 5 minutes or until a metallic green film or scum is apparent on the fluid surface.

5. Rinse the slide with a stream of distilled water. Then flood it with distilled water, and allow it to lie flat until the slide becomes translucent and takes on a pink cast. Then stand the slide on its long edge on the paper towel, and allow it to dry completely. Once the slide is dry, you can begin your observations.

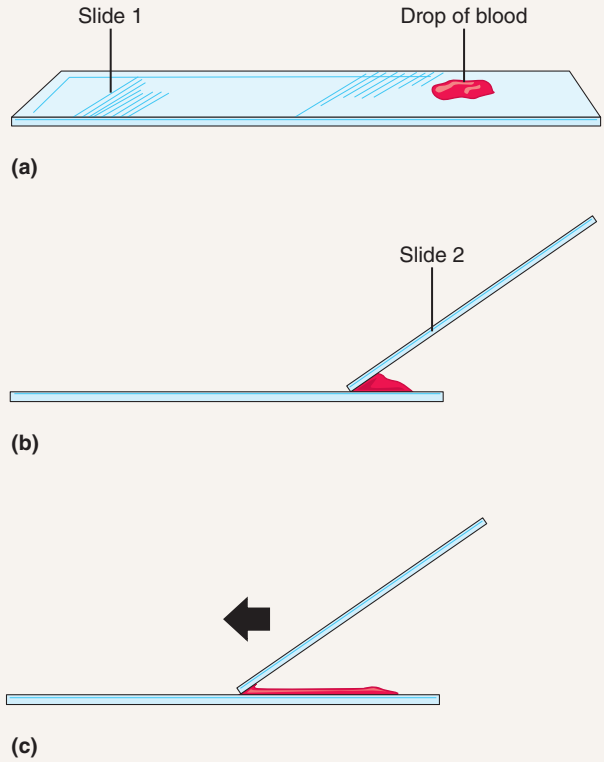

Figure 29.2 Procedure for making a blood smear. **(a)** Place a drop of blood on slide 1 approximately ½ inch from one end. **(b)** Hold slide 2 at a 30° to 40° angle to slide 1 (it should touch the drop of blood) and allow blood to spread along entire bottom edge of angled slide. **(c)** Smoothly advance slide 2 to end of slide 1 (blood should run out before reaching the end of slide 1). Then lift slide 2 away from slide 1 and place slide 1 on a paper towel. Dispose of slide 2 in the appropriate container.

6. Obtain a microscope and scan the slide under low power to find the area where the blood smear is the thinnest. After scanning the slide in low power to find the areas with the largest numbers of WBCs, read the following descriptions of cell types, and find each one in the art illustrating blood cell types (in Figure 29.1 and Table 29.1). (The formed elements are also shown in **Figure 29.3**, p. 430, and Figure 29.4.) Then, switch to the oil immersion lens, and observe the slide carefully to identify each cell type.

7. Set your prepared slide aside for use in Activity 3.

Erythrocytes

Erythrocytes, or red blood cells, which average 7.5 µm in diameter, vary in color from an orange-pink color to pale pink, depending on the effectiveness of the stain. They have a distinctive biconcave disc shape and appear paler in the center than at the edge (see Figure 29.3).

As you observe the slide, notice that the red blood cells are by far the most numerous blood cells seen in the

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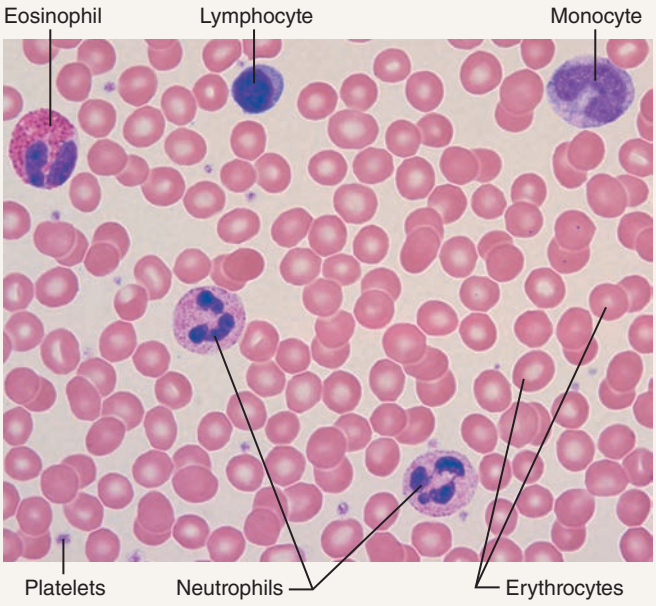


Figure 29.3 Photomicrograph of a human blood smear stained with Wright's stain (765×).

field. Their number averages 4.5 million to 5.5 million cells per cubic millimeter of blood (for women and men, respectively).

Red blood cells differ from the other blood cells because they are anucleate (lacking a nucleus) when mature and circulating in the blood. As a result, they are unable to reproduce or repair damage and have a limited life span of 100 to 120 days, after which they begin to fragment and are destroyed, mainly in the spleen.

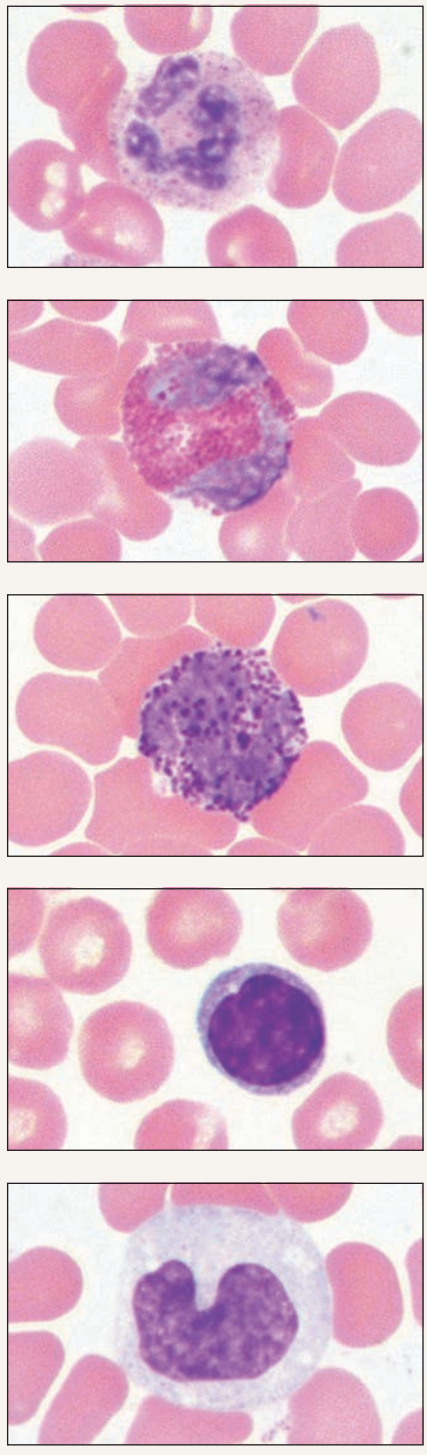
In various anemias, the red blood cells may appear pale (an indication of decreased hemoglobin content) or may be nucleated (an indication that the bone marrow is turning out cells prematurely). ✚

Leukocytes

Leukocytes, or white blood cells, are nucleated cells that are formed in the bone marrow from the same stem cells *(hemocytoblast)* as red blood cells. They are much less numerous than the red blood cells, averaging from 4800 to 10,800 cells per cubic millimeter. The life span of leukocytes varies. They can survive for minutes or decades, depending on the type of leukocyte and tissue activity. Basically, white blood cells are protective, pathogen-destroying cells that are transported to all parts of the body in the blood or lymph. Important to their protective function is their ability to move in and out of blood vessels, a process called **diapedesis,** and to wander through body tissues by **amoeboid motion** to reach sites of inflammation or tissue destruction. They are classified into two major groups, depending on whether or not they contain conspicuous granules in their cytoplasm.

Granulocytes make up the first group. The granules in their cytoplasm stain differentially with Wright's stain, and they have peculiarly lobed nuclei, which often consist of expanded nuclear regions connected by thin strands of nucleoplasm. There are three types of granulocytes: **neutrophils, eosinophils,** and **basophils.**

The second group, **agranulocytes,** contains no *visible* cytoplasmic granules. Although found in the bloodstream, they are much more abundant in lymphoid tissues. There are two types of agranulocytes: **lymphocytes** and **monocytes.** The specific characteristics of leukocytes are described in Table 29.1. Photomicrographs of the leukocytes illustrate their different appearances (**Figure 29.4**).



(a) Neutrophil; multilobed nucleus, pale red and blue cytoplasmic granules

(b) Eosinophil; bilobed nucleus, red cytoplasmic granules

(c) Basophil; bilobed nucleus, purplish black cytoplasmic granules

(d) Small lymphocyte; large spherical nucleus

(e) Monocyte; kidney-shaped nucleus

Figure 29.4 Leukocytes. In each case, the leukocytes are surrounded by erythrocytes (1330×, Wright's stain).

Students are often asked to list the leukocytes in order from the most abundant to the least abundant. The following silly phrase may help you with this task: *N*ever *l*et *m*onkeys *e*at *b*ananas (neutrophils, lymphocytes, monocytes, eosinophils, basophils).

Platelets

Platelets are cell fragments of large multinucleate cells **(megakaryocytes)** formed in the bone marrow. They appear as darkly staining, irregularly shaped bodies interspersed among the blood cells (see Figure 29.3). The normal platelet count in blood ranges from 150,000 to 400,000 per cubic millimeter. Platelets are instrumental in the clotting process that occurs in plasma when blood vessels are ruptured.

After you have identified these cell types on your slide, observe charts and three-dimensional models of blood cells if these are available. Do not dispose of your slide, as you will use it later for the differential white blood cell count.

Hematologic Tests

When someone enters a hospital as a patient, several hematologic tests are routinely done to determine general level of health as well as the presence of pathologic conditions. You will be conducting the most common of these tests in this exercise.

Materials such as cotton balls, lancets, and alcohol swabs are used in nearly all of the following diagnostic tests. These supplies are at the general supply area and should be properly disposed of (glassware to the bleach bucket, lancets in a designated disposal container, and disposable items to the autoclave bag) immediately after use.

Other necessary supplies and equipment are at specific supply areas marked according to the test with which they are used. Since nearly all of the tests require a finger stick, if you will be using your own blood it might be wise to quickly read through the tests to determine in which instances more than one preparation can be done from the same finger stick. A little planning will save you the discomfort of multiple finger sticks.

An alternative to using blood obtained from the finger stick technique is using heparinized blood samples supplied by your instructor. The purpose of using heparinized tubes is to prevent the blood from clotting. Thus blood collected and stored in such tubes will be suitable for all tests except coagulation time testing.

Total White and Red Blood Cell Counts

A **total WBC count** or **total RBC count** determines the total number of that cell type per unit volume of blood. Total WBC and RBC counts are a routine part of any physical exam. Most clinical agencies use computers to conduct these counts. Total WBC and RBC counts will not be done here, but the importance of such counts (both normal and abnormal values) is briefly described below.

Total White Blood Cell Count

Since white blood cells are an important part of the body's defense system, it is essential to note any abnormalities in them.

Leukocytosis, an abnormally high WBC count, may indicate bacterial or viral infection, metabolic disease, hemorrhage, or poisoning by drugs or chemicals. A decrease in the white cell number below 4000/mm^3 **(leukopenia)** may indicate infectious hepatitis or cirrhosis, tuberculosis, or excessive antibiotic or X-ray therapy. A person with leukopenia lacks the usual protective mechanisms. **Leukemia,** a malignant disorder of the lymphoid tissues characterized by uncontrolled proliferation of abnormal WBCs accompanied by a reduction in the number of RBCs and platelets, is detectable not only by a total WBC count but also by a differential WBC count. ✚

Total Red Blood Cell Count

Since RBCs are absolutely necessary for oxygen transport, a doctor typically investigates any excessive change in their number immediately.

An increase in the number of RBCs **(polycythemia)** may result from bone marrow cancer or from living at high altitudes where less oxygen is available. A decrease in the number of RBCs results in anemia. The term **anemia** simply indicates a decreased oxygen-carrying capacity of blood that may result from a decrease in RBC number or size or a decreased hemoglobin content of the RBCs. A decrease in RBCs may result suddenly from hemorrhage or more gradually from conditions that destroy RBCs or hinder RBC production. ✚

Differential White Blood Cell Count

To make a **differential white blood cell count,** 100 WBCs are counted and classified according to type. Such a count is routine in a physical examination and in diagnosing illness, since any abnormality in percentages of WBC types may indicate a problem and the source of pathology.

Activity 3

Conducting a Differential WBC Count

1. Use the slide prepared for the identification of the blood cells in Activity 2 or a prepared slide provided by your instructor. Begin at the edge of the smear and move the slide in a systematic manner on the microscope stage—either up and down or from side to side (as indicated in **Figure 29.5** on p. 432).

2. Record each type of white blood cell you observe by making a count in the first blank column of the **Activity 3 chart** on p. 432 (for example, 𝍸 || = 7 cells) until you have observed and recorded a total of 100 WBCs. Using the following equation, compute the percentage of each WBC type counted, and record the percentages on

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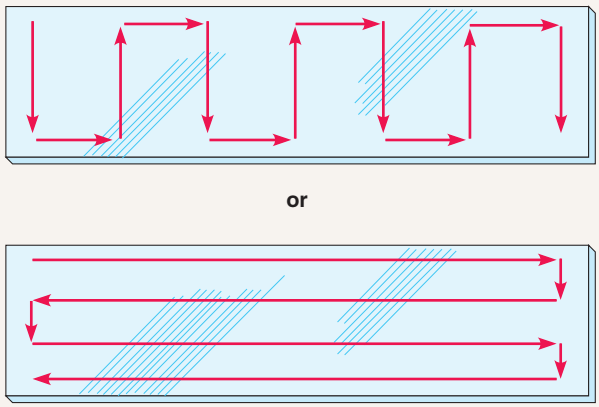

Figure 29.5 Alternative methods of moving the slide for a differential WBC count.

the Hematologic Test Data Sheet on the last page of the exercise, preceding the Review Sheet.

$$\text{Percent (\%)} = \frac{\text{\# observed}}{\text{Total \# counted}} \times 100$$

3. Select a slide marked "Unknown sample," record the slide number, and use the count chart below to conduct a differential count. Record the percentages on the data sheet (p. 438).

How does the differential count from the unknown sample slide compare to the normal percentages given for each type in Table 29.1?

_____

_____

Activity 3: Count of 100 WBCs		
	Number observed	
Cell type	Student blood smear	Unknown sample # ____
Neutrophils		
Eosinophils		
Basophils		
Lymphocytes		
Monocytes		

Using the text and other references, try to determine the blood pathology on the unknown slide. Defend your answer.

_____

_____

4. How does your differential white blood cell count compare to the percentages given in Table 29.1?

_____

Hematocrit

The **hematocrit** is routinely determined when anemia is suspected. Centrifuging whole blood spins the formed elements to the bottom of the tube, with plasma forming the top layer (see Figure 29.1). Since the blood cell population is primarily RBCs, the hematocrit is generally considered equivalent to the RBC volume, and this is the only value reported. However, the relative percentage of WBCs can be differentiated, and both WBC and plasma volume will be reported here. Normal hematocrit values for the male and female, respectively, are 47.0 ± 5 and 42.0 ± 5.

Prepare for lab: Watch the Pre-Lab Video
MasteringA&P®>Study Area > Pre-Lab Videos

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Activity 4

Determining the Hematocrit

The hematocrit is determined by the micromethod, so only a drop of blood is needed. If possible (and the centrifuge allows), all members of the class should prepare their capillary tubes at the same time so the centrifuge can be run only once.

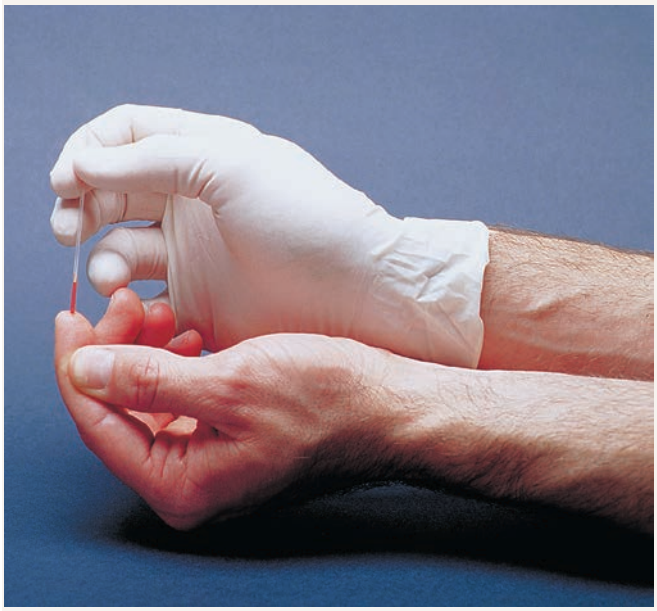
1. Obtain two heparinized capillary tubes, capillary tube sealer or modeling clay, a lancet, alcohol swabs, and some cotton balls.

2. If you are using your own blood, use an alcohol swab to cleanse a finger, prick the finger with a lancet, and allow the blood to flow freely. Wipe away the first few drops and, holding the red-line-marked end of the capillary tube to the blood drop, allow the tube to fill at least three-fourths full by capillary action (**Figure 29.6a**). If the blood is not flowing freely, the end of the capillary tube will not be completely submerged in the blood during filling, air will enter, and you will have to prepare another sample.

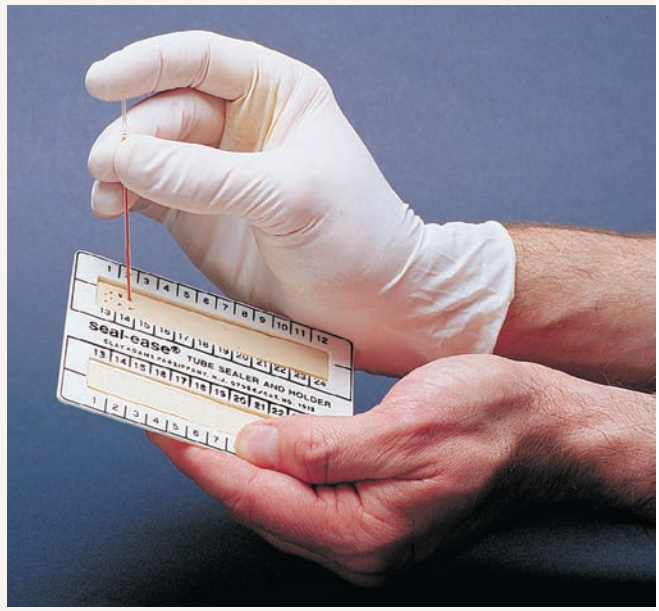
If you are using instructor-provided blood, simply immerse the red-marked end of the capillary tube in the blood sample and fill it three-quarters full as just described.

3. Plug the blood-containing end by pressing it into the capillary tube sealer or clay (Figure 29.6b). Prepare a second tube in the same manner.

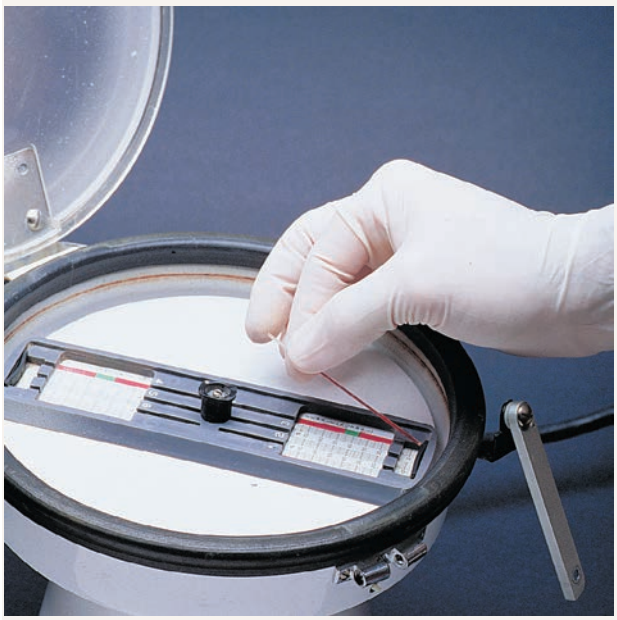
4. Place the prepared tubes opposite one another in the radial grooves of the microhematocrit centrifuge with the sealed ends abutting the rubber gasket at the centrifuge periphery (Figure 29.6c). This loading procedure balances the centrifuge and prevents blood from spraying everywhere by centrifugal force. *Make a note of the numbers of the grooves your tubes are in.* When all the tubes have been loaded, make sure the centrifuge is properly balanced, and secure the centrifuge cover. Turn the centrifuge on, and set the timer for 4 or 5 minutes.



(a)



(b)



(c)

Figure 29.6 Steps in a hematocrit determination.
(a) Fill a heparinized capillary tube with blood.
(b) Plug the blood-containing end of the tube with clay.
(c) Place the tube in a microhematocrit centrifuge. (Centrifuge must be balanced.)

5. Determine the percentage of RBCs, WBCs, and plasma by using the microhematocrit reader. The RBCs are the bottom layer, the plasma is the top layer, and the WBCs are the buff-colored layer between the two. If the reader is not available, use a millimeter ruler to measure the length of the filled capillary tube occupied by each element, and compute its percentage by using the following formula:

$$\frac{\text{Height of the column composed of the element (mm)}}{\text{Height of the original column of whole blood (mm)}} \times 100$$

Record your calculations below and on the data sheet (p. 438).

% RBC _____ % WBC _____ % plasma _____

Usually WBCs constitute 1% of the total blood volume. How do your blood values compare to this figure and to the normal percentages for RBCs and plasma? (See Figure 29.1.)

_____

As a rule, a hematocrit is considered a more accurate test than the total RBC count for determining the RBC composition of the blood. A hematocrit within the normal range generally indicates a normal RBC number, whereas an abnormally high or low hematocrit is cause for concern.

29

Hemoglobin Concentration

As noted earlier, a person can be anemic even with a normal RBC count. Since hemoglobin (Hb) is the RBC protein responsible for oxygen transport, perhaps the most accurate way of measuring the oxygen-carrying capacity of the blood is to determine its hemoglobin content. Oxygen, which combines reversibly with the heme (iron-containing portion) of the hemoglobin molecule, is picked up by the blood cells in the lungs and unloaded in the tissues. Thus, the more hemoglobin molecules the RBCs contain, the more oxygen they will be able to transport. Normal blood contains 12 to 18 g of hemoglobin per 100 ml of blood. Hemoglobin content in men is slightly higher (13 to 18 g) than in women (12 to 16 g).

Activity 5

Determining Hemoglobin Concentration

Several techniques have been developed to estimate the hemoglobin content of blood, ranging from the old, rather inaccurate Tallquist method to expensive hemoglobinometers, which are precisely calibrated and yield highly accurate results. Directions for both the Tallquist method and a hemoglobinometer are provided here.

Tallquist Method

1. Obtain a Tallquist hemoglobin scale, test paper, lancets, alcohol swabs, and cotton balls.

2. Use instructor-provided blood or prepare the finger as previously described. (For best results, make sure the alcohol evaporates before puncturing your finger.) Place one good-sized drop of blood on the special absorbent paper provided with the color scale. The blood stain should be larger than the holes on the color scale.

3. As soon as the blood has dried and loses its glossy appearance, match its color, under natural light, with the color standards by moving the specimen under the comparison scale so that the blood stain appears at all the various apertures. (The blood should not be allowed to dry to a brown color, as this will result in an inaccurate reading.) Because the colors on the scale represent 1% variations in hemoglobin content, it may be necessary to estimate the percentage if the color of your blood sample is intermediate between two color standards.

4. On the data sheet (p. 438) record your results as the percentage of hemoglobin concentration and as grams per 100 ml of blood.

Hemoglobinometer Determination

1. Obtain a hemoglobinometer, hemolysis applicator, alcohol swab, and lens paper, and bring them to your bench.

(a) A drop of blood is added to the moat plate of the blood chamber. The blood must flow freely.

(b) The blood sample is hemolyzed with a wooden hemolysis applicator. Complete hemolysis requires 35 to 45 seconds.

(c) The charged blood chamber is inserted into the slot on the side of the hemoglobinometer.

(d) The colors of the green split screen are found by moving the slide with the right index finger. When the two colors match in density, the grams/100 ml and % Hb are read on the scale.

Figure 29.7 Hemoglobin determination using a hemoglobinometer.

Test the hemoglobinometer light source to make sure it is working; if not, request new batteries before proceeding and test it again.

2. Remove the blood chamber from the slot in the side of the hemoglobinometer and disassemble the blood chamber by separating the glass plates from the metal clip. Notice as you do this that the larger glass plate has an H-shaped depression cut into it that acts as a moat to hold the blood, whereas the smaller glass piece is flat and serves as a coverslip.

3. Clean the glass plates with an alcohol swab, and then wipe them dry with lens paper. Hold the plates by their sides to prevent smearing during the wiping process.

4. Reassemble the blood chamber (remember: larger glass piece on the bottom with the moat up), but leave the moat plate about halfway out to provide adequate exposed surface to charge it with blood.

5. Obtain a drop of blood (from the provided sample or from your fingertip as before), and place it on the depressed area of the moat plate that is closest to you (**Figure 29.7a**).

6. Using the wooden hemolysis applicator, stir or agitate the blood to rupture (lyse) the RBCs (Figure 29.7b). This usually takes 35 to 45 seconds. Hemolysis is complete when the blood appears transparent rather than cloudy.

7. Push the blood-containing glass plate all the way into the metal clip and then firmly insert the charged blood chamber back into the slot on the side of the instrument (Figure 29.7c).

8. Hold the hemoglobinometer in your left hand with your left thumb resting on the light switch located on the underside of the instrument. Look into the eyepiece and notice that there is a green area divided into two halves (a split field).

9. With the index finger of your right hand, slowly move the slide on the right side of the hemoglobinometer back and forth until the two halves of the green field match (Figure 29.7d).

10. Note and record on the data sheet (p. 438) the grams of Hb (hemoglobin)/100 ml of blood indicated on the uppermost scale by the index mark on the slide. Also record % Hb, indicated by one of the lower scales.

11. Disassemble the blood chamber once again, and carefully place its parts (glass plates and clip) into a bleach-containing beaker.

Generally speaking, the relationship between the hematocrit and grams of hemoglobin per 100 ml of blood is 3:1—for example, a hematocrit of 36% with 12 g of Hb per 100 ml of blood is a ratio of 3:1. How do your values compare?

_____

Record on the data sheet (p. 438) the value obtained from your data.

Bleeding Time

Normally a sharp prick of the finger or earlobe results in bleeding that lasts from 2 to 7 minutes (Ivy method) or 0 to 5 minutes (Duke method), although other factors such as altitude affect the time. How long the bleeding lasts is referred to as **bleeding time** and tests the ability of platelets to stop bleeding in capillaries and small vessels. Absence of some clotting factors may affect bleeding time, but prolonged bleeding time is most often associated with deficient or abnormal platelets.

Coagulation Time

Blood clotting, or **coagulation,** is a protective mechanism that minimizes blood loss when blood vessels are ruptured. This process requires the interaction of many substances normally present in the plasma (clotting factors, or procoagulants) as well as some released by platelets and injured tissues. Basically hemostasis proceeds as follows (**Figure 29.8a**, p. 436): The injured tissues and platelets release **tissue factor (TF)** and **PF_3** (**platelet factor 3**) respectively, which trigger the clotting mechanism, or cascade. Tissue factor and PF_3 interact with other blood protein clotting factors and calcium ions to form **prothrombin activator,** which in turn converts **prothrombin** (present in plasma) to **thrombin.** Thrombin then acts enzymatically to polymerize (combine) the soluble **fibrinogen** proteins (present in plasma) into insoluble **fibrin,** which forms a meshwork of strands that traps the RBCs and forms the basis of the clot (Figure 29.8b). Normally, blood removed from the body clots within 2 to 6 minutes.

29

Activity 6

Determining Coagulation Time

1. Obtain a *nonheparinized* capillary tube, a timer (or watch), a lancet, cotton balls, a triangular file, and alcohol swabs.

2. Clean and prick the finger to produce a free flow of blood. Discard the lancet in the disposal container.

3. Place one end of the capillary tube in the blood drop, and hold the opposite end at a lower level to collect the sample.

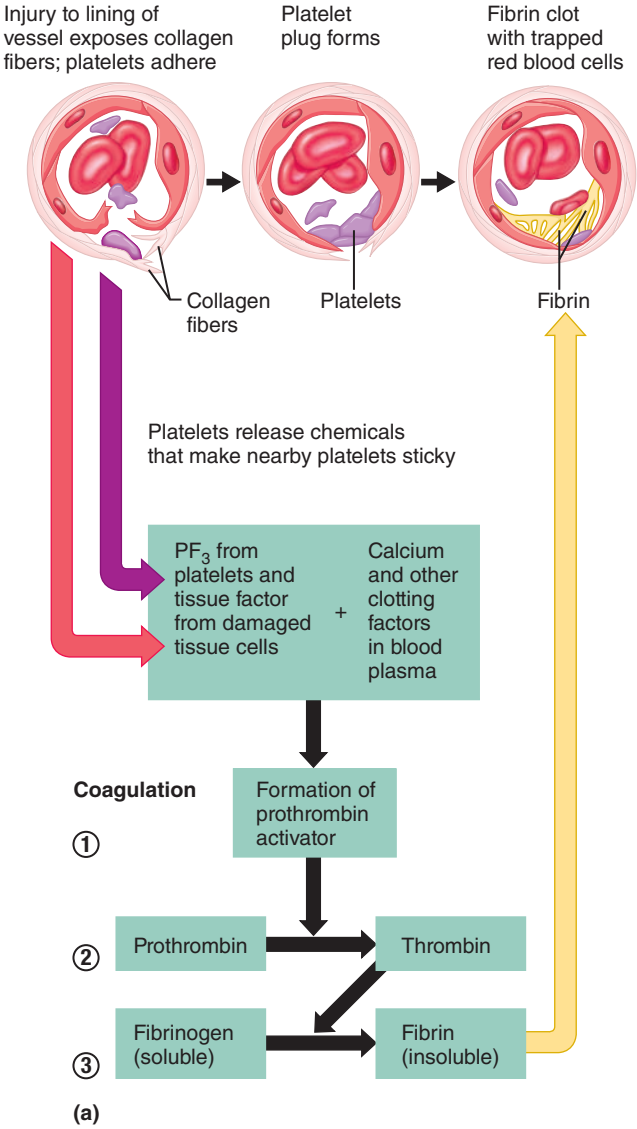
4. Lay the capillary tube on a paper towel after collecting the sample.

Record the time. _____

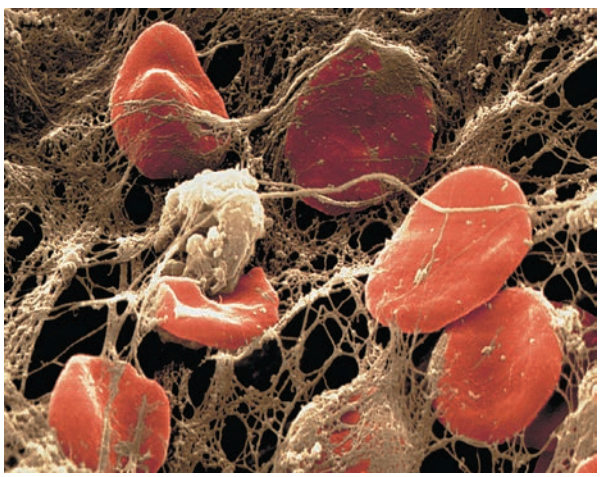
5. At 30-second intervals, make a small nick on the tube close to one end with the triangular file, and then carefully break the tube. Slowly separate the ends to see whether a gel-like thread of fibrin spans the gap. When this occurs, record below and on the data sheet (p. 438) the time for coagulation to occur. Are your results within the normal time range?

_____

6. Put used supplies in the autoclave bag and broken capillary tubes into the sharps container.



(a)



(b)

Figure 29.8 Events of hemostasis and blood clotting. **(a)** Simple schematic of events. Steps numbered 1–3 represent the major events of coagulation. **(b)** Photomicrograph of RBCs trapped in a fibrin mesh (2700×).

Blood Typing

Blood typing is a system of blood classification based on the presence of specific glycoproteins on the outer surface of the RBC plasma membrane. Such proteins are called **antigens,** or **agglutinogens,** and are genetically determined. For ABO blood groups, these antigens are accompanied by plasma proteins, called **antibodies** or **agglutinins.** These antibodies act against RBCs carrying antigens that are not present on the person's own RBCs. If the donor blood type doesn't match, the recipient's antibodies react with the donor's blood antigens, causing the RBCs to clump, agglutinate, and eventually hemolyze. It is because of this phenomenon that a person's blood must be carefully typed before a whole blood or packed cell transfusion.

Several blood typing systems exist, based on the various possible antigens, but the factors routinely typed for are antigens of the ABO and Rh blood groups which are most commonly involved in transfusion reactions. The basis of the ABO typing is shown in **Table 29.2**.

Individuals whose red blood cells carry the Rh antigen are Rh positive (approximately 85% of the U.S. population); those lacking the antigen are Rh negative. Unlike ABO blood groups, the blood of neither Rh-positive (Rh^+) nor Rh-negative (Rh^-) individuals carries preformed anti-Rh antibodies. This is understandable in the case of the Rh-positive individual. However, Rh-negative persons who receive transfusions of Rh-positive blood become sensitized by the Rh antigens of the donor RBCs, and their systems begin to produce anti-Rh antibodies. On subsequent exposures to Rh-positive blood, typical transfusion reactions occur, resulting in the clumping and hemolysis of the donor blood cells.

Prepare for lab: Watch the Pre-Lab Video
MasteringA&P®>Study Area>Pre-Lab Videos

Activity 7

Typing for ABO and Rh Blood Groups

Blood may be typed on microscope slides or using blood test cards. Each method is described in this activity. The artificial blood kit does not use any body fluids and produces results similar to but not identical to results for human blood.

Typing Blood Using Glass Slides

1. Obtain two clean microscope slides, a wax marking pencil, anti-A, anti-B, and anti-Rh typing sera, toothpicks, lancets, alcohol swabs, medicine dropper, and the Rh typing box.

2. Divide slide 1 into halves with the wax marking pencil. Label the lower left-hand corner "anti-A" and the lower right-hand corner "anti-B." Mark the bottom of slide 2 "anti-Rh."

3. Place one drop of anti-A serum on the *left* side of slide 1. Place one drop of anti-B serum on the *right* side of slide 1. Place one drop of anti-Rh serum in the center of slide 2.

4. If you are using your own blood, cleanse your finger with an alcohol swab, pierce the finger with a lancet, and wipe away the first drop of blood. Obtain 3 drops of freely flowing blood, placing one drop on each side of slide 1 and a drop on slide 2. Immediately dispose of the lancet in a designated disposal container.

Table 29.2 ABO Blood Typing

ABO blood type	Antigens present on RBC membranes	Antibodies present in plasma	% of U.S. population		
			White	Black	Asian
A	A	Anti-B	40	27	28
B	B	Anti-A	11	20	27
AB	A and B	None	4	4	5
O	Neither	Anti-A and anti-B	45	49	40

If using instructor-provided animal blood or red blood cells treated with EDTA (an anticoagulant), use a medicine dropper to place one drop of blood on each side of slide 1 and a drop of blood on slide 2.

5. Quickly mix each blood-antiserum sample with a *fresh* toothpick. Then dispose of the toothpicks and used alcohol swab in the autoclave bag.

6. Place slide 2 on the Rh typing box and rock gently back and forth. (A slightly higher temperature is required for precise Rh typing than for ABO typing.)

7. After 2 minutes, observe all three blood samples for evidence of clumping. The agglutination that occurs in the positive test for the Rh factor is very fine and difficult to interpret; thus if there is any question, observe the slide under the microscope. Record your observations in the **Activity 7 chart.**

8. Interpret your ABO results (see the examples of each type) in **Figure 29.9**. If clumping was observed on slide 2, you are Rh positive. If not, you are Rh negative.

9. Record your blood type on the data sheet (p. 438).

10. Put the used slides in the bleach-containing bucket at the general supply area; put disposable supplies in the autoclave bag.

Activity 7: Blood Typing

Result	Observed (+)	Not observed (–)
Presence of clumping with anti-A		
Presence of clumping with anti-B		
Presence of clumping with anti-Rh		

Using Blood Typing Cards

1. Obtain a blood typing card marked A, B, and Rh, dropper bottles of anti-A serum, anti-B serum, and anti-Rh serum, toothpicks, lancets, and alcohol swabs.

2. Place a drop of anti-A serum in the spot marked anti-A, place a drop of anti-B serum on the spot marked anti-B, and place a drop of anti-Rh serum on the spot marked anti-Rh (or anti-D).

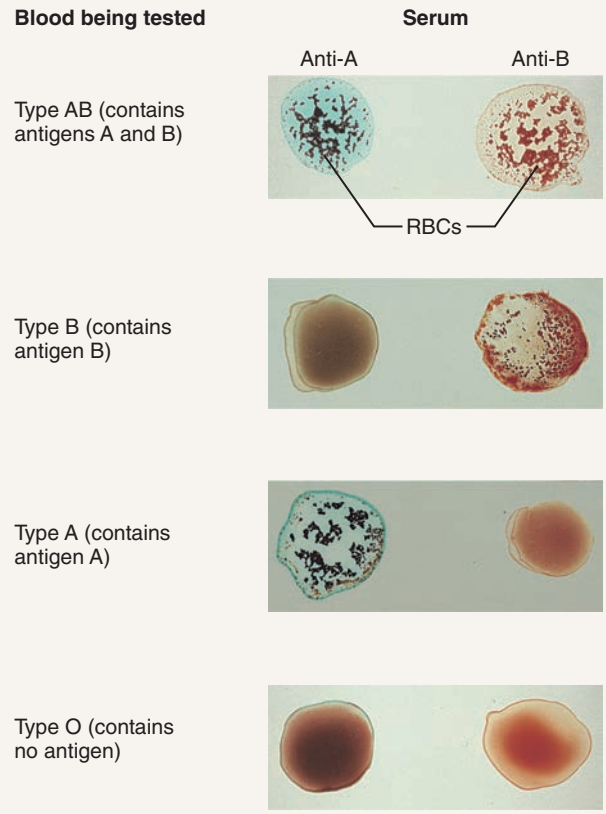


Figure 29.9 Blood typing of ABO blood types. When serum containing anti-A or anti-B antibodies (agglutinins) is added to a blood sample, agglutination will occur between the antibody and the corresponding antigen (agglutinogen A or B). As illustrated, agglutination occurs with both sera in blood group 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.

3. Carefully add a drop of blood to each of the spots marked "Blood" on the card. If you are using your own blood, refer to step 4 in the Activity 7 section Typing Blood Using Glass Slides. Immediately discard the lancet in the designated disposal container.

4. Using a new toothpick for each test, mix the blood sample with the antibody. Dispose of the toothpicks appropriately.

Text continues on next page. →

5. Gently rock the card to allow the blood and antibodies to mix.

6. After 2 minutes, observe the card for evidence of clumping. The Rh clumping is very fine and may be difficult to observe. Record your observations in the Activity 7: Blood Typing chart. (Use Figure 29.9 to interpret your results.)

7. Record your blood type on the data sheet below, and discard the card in an autoclave bag.

Activity 8

Observing Demonstration Slides

Look at the slides of *macrocytic hypochromic anemia, microcytic hypochromic anemia, sickle cell anemia, lymphocytic leukemia* (chronic), and *eosinophilia* that have been put on demonstration by your instructor. Record your observations in the appropriate section of the Review Sheet. You can refer to your notes, the text, and other references later to respond to questions about the blood pathologies represented on the slides.

Cholesterol Concentration in Plasma

Atherosclerosis is the disease process in which the body's blood vessels become increasingly occluded, or blocked, by plaques. By narrowing the arteries, the plaques can contribute to hypertensive heart disease. They also serve as starting points for the formation of blood clots (thrombi), which may break away and block smaller vessels farther downstream in the circulatory pathway and cause heart attacks or strokes.

Cholesterol is a major component of the smooth muscle plaques formed during atherosclerosis. No physical examination of an adult is considered complete until cholesterol levels are assessed along with other risk factors. A normal value for total plasma cholesterol in adults ranges from 130 to 200 mg per 100 ml of plasma; you will use blood to make such a determination.

Although the total plasma cholesterol concentration is valuable information, it may be misleading, particularly if a person's high-density lipoprotein (HDL) level is high and low-density lipoprotein (LDL) level is relatively low. Cholesterol, being water insoluble, is transported in the blood complexed to lipoproteins. In general, cholesterol bound into HDLs is destined to be degraded by the liver and then eliminated from the body, whereas that forming part of the LDLs is "traveling" to the body's tissue cells. When LDL levels are excessive, cholesterol is deposited in the blood vessel walls; hence, LDLs are considered to carry the "bad" cholesterol.

Activity 9

Measuring Plasma Cholesterol Concentration

1. Go to the appropriate supply area, and obtain a cholesterol test card and color scale, lancet, and alcohol swab.

2. Clean your fingertip with the alcohol swab, allow it to dry, then prick it with a lancet. Place a drop of blood on the test area of the card. Put the lancet in the designated disposal container.

3. After 3 minutes, remove the blood sample strip from the card and discard in the autoclave bag.

4. Analyze the underlying test spot, using the included color scale. Record the cholesterol level below and on the **Hematologic Test Data Sheet**.

Total cholesterol level _____ mg/dl

5. Before leaving the laboratory, use the spray bottle of bleach solution, and saturate a paper towel to thoroughly wash down your laboratory bench.

29

Hematologic Test Data Sheet

Differential WBC count:

WBC	Student blood smear	Unknown sample # ____
% neutrophils	_____	_____
% eosinophils	_____	_____
% basophils	_____	_____
% lymphocytes	_____	_____
% monocytes	_____	_____

Hematocrit:

RBC _____ % of blood volume

WBC _____ % of blood volume

Plasma _____ % of blood

not generally reported

Hemoglobin (Hb) content:

Tallquist method: _____ g/100 ml of blood; _____ % Hb

Hemoglobinometer (type: _____)

_____ g/100 ml of blood; _____ %Hb

Ratio (hematocrit to grams of Hb per 100 ml of blood):

_____

Coagulation time: _____

Blood typing:

ABO group _____ Rh factor _____

Total cholesterol level: _____ mg/dl of blood

EXERCISE 29

REVIEW SHEET
Blood

Name _____ Lab Time/Date _____

Composition of Blood

1. What is the blood volume of an average-size adult male? _____ liters; an average adult female? _____ liters
2. What determines whether blood is bright red or a dull brick red? _____

_____

3. Use the key to identify the cell type(s) or blood elements that fit the following descriptive statements. Some terms will be used more than once.

Key: a. red blood cell
b. megakaryocyte
c. eosinophil
d. basophil
e. monocyte
f. neutrophil
g. lymphocyte
h. formed elements
i. plasma

_____ 1. most numerous leukocyte

_____, _____, and _____ 2. granulocytes (3)

_____ 3. also called an erythrocyte; anucleate formed element

_____, _____, _____ 4. phagocytic leukocytes (3)

_____, _____ 5. agranulocytes

_____ 6. precursor cell of platelets

_____ 7. (a) through (g) are all examples of these

_____ 8. involved in destroying parasitic worms

_____ 9. releases histamine; promotes inflammation

_____ 10. produces antibodies

_____ 11. transports oxygen

_____ 12. primarily water, noncellular; the fluid matrix of blood

_____ 13. exits a blood vessel to develop into a macrophage

_____, _____, _____,

_____, _____ 14. the five types of white blood cells

4. List four classes of nutrients normally found in plasma. _____,

_____, _____, and _____

Name two gases. _____ and _____

Name three ions. _____, _____, and _____

5. Describe the consistency and color of the plasma you observed in the laboratory. _____

_____

6. What is the average life span of a red blood cell? How does its anucleate condition affect this life span?

_____

_____

_____

7. From memory, describe the structural characteristics of each of the following blood cell types as accurately as possible, and note the percentage of each in the total white blood cell population.

eosinophils: _____

_____

neutrophils: _____

_____

lymphocytes: _____

_____

basophils: _____

_____

monocytes: _____

_____

8. Correctly identify the blood pathologies described in column A by matching them with selections from column B:

Column A	**Column B**
_____ 1. abnormal increase in the number of WBCs	a. anemia
_____ 2. abnormal increase in the number of RBCs	b. leukocytosis
_____ 3. condition of too few RBCs or of RBCs with hemoglobin deficiencies	c. leukopenia
_____ 4. abnormal decrease in the number of WBCs	d. polycythemia

Hematologic Tests

9. Broadly speaking, why are hematologic studies of blood so important in diagnosing disease?

10. In the chart below, record information from the blood tests you read about or conducted. Complete the chart by recording values for healthy male adults and indicating the significance of high or low values for each test.

Test	Student test results	Normal values (healthy male adults)	Significance	
			High values	Low values
Total WBC count	No data			
Total RBC count	No data			
Hematocrit				
Hemoglobin determination				
Bleeding time	No data			
Coagulation time				

11. Why is a differential WBC count more valuable than a total WBC count when trying to determine the specific source of pathology?

12. What name is given to the process of RBC production? (Consult an appropriate reference as necessary.)

What hormone acts as a stimulus for this process?

Why might patients with kidney disease suffer from anemia?

How can such patients be treated?

13. Discuss the effect of each of the following factors on RBC count. Consult an appropriate reference as necessary, and explain your reasoning.

long-term effect of athletic training (for example, running 4 to 5 miles per day over a period of 6 to 9 months):

a permanent move from sea level to a high-altitude area: _____

_____

_____

14. Define *hematocrit.* _____

15. If you had a high hematocrit, would you expect your hemoglobin determination to be high or low? _____

Why? _____

_____

16. What is an anticoagulant? _____

Name two anticoagulants used in conducting the hematologic tests. _____

and _____

What is the body's natural anticoagulant? _____

17. If your blood clumped with both anti-A and anti-B sera, your ABO blood type would be _____

To what ABO blood groups could you give blood? _____

From which ABO donor types could you receive blood? _____

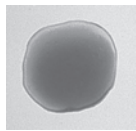
Which ABO blood type is most common? _____ Least common? _____

18. What blood type is theoretically considered the universal donor? _____ Why? _____

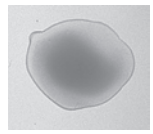
_____

19. Assume the blood of two patients has been typed for ABO blood type.

Typing results
Mr. Adams:

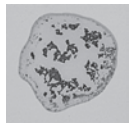


Blood drop and anti-A serum

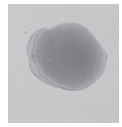


Blood drop and anti-B serum

Typing results
Mr. Calhoon:



Blood drop and anti-A serum



Blood drop and anti-B serum

On the basis of these results, Mr. Adams has type _____ blood, and Mr. Calhoon has type _____ blood.

20. Explain why an Rh-negative person does not have a transfusion reaction on the first exposure to Rh-positive blood but *does* have a reaction on the second exposure. _____

_____

What happens when an ABO blood type is mismatched for the first time? _____

_____

21. Record your observations of the five demonstration slides viewed.

a. Macrocytic hypochromic anemia: _____

b. Microcytic hypochromic anemia: _____

_____

c. Sickle cell anemia: _____

d. Lymphocytic leukemia (chronic): _____

_____

e. Eosinophilia: _____

Which of the slides above (a through e) corresponds with the following conditions?

_____ 1. iron-deficient diet

_____ 2. a type of bone marrow cancer

_____ 3. genetic defect that causes hemoglobin to become sharp/spiky

_____ 4. lack of vitamin B_{12}

_____ 5. a tapeworm infestation in the body

_____ 6. a bleeding ulcer

22. Provide the normal, or at least "desirable," range for plasma cholesterol concentration.

_____ mg/100 ml

23. Describe the relationship between high blood cholesterol levels and cardiovascular diseases such as hypertension, heart attacks, and strokes.

_____

_____

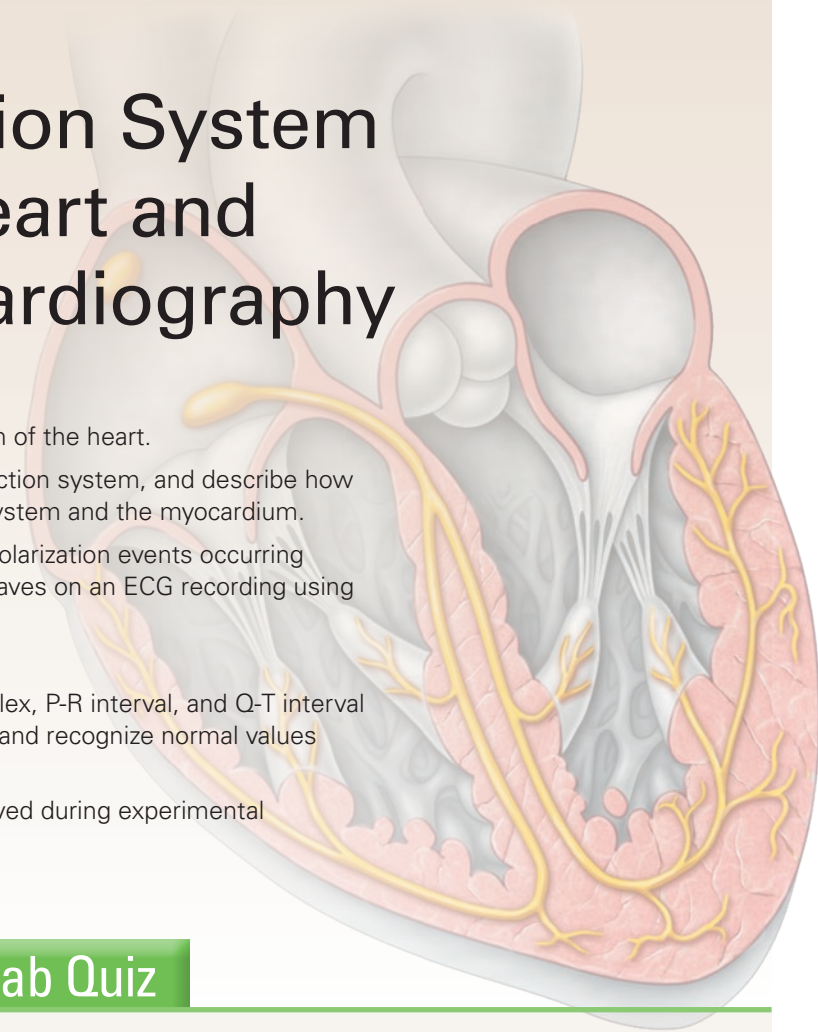
_____

_____

_____

EXERCISE

31 Conduction System of the Heart and Electrocardiography



Objectives

- ☐ State the function of the intrinsic conduction system of the heart.
- ☐ List and identify the elements of the intrinsic conduction system, and describe how impulses are initiated and conducted through this system and the myocardium.
- ☐ Interpret the ECG in terms of depolarization and repolarization events occurring in the myocardium; and identify the P, QRS, and T waves on an ECG recording using an ECG recorder or BIOPAC®.
- ☐ Define *tachycardia, bradycardia,* and *fibrillation.*
- ☐ Calculate the heart rate, durations of the QRS complex, P-R interval, and Q-T interval from an ECG obtained during the laboratory period, and recognize normal values for the durations of these events.
- ☐ Describe and explain the changes in the ECG observed during experimental conditions such as exercise or breath holding.

Materials

- ECG or BIOPAC® equipment:*

ECG recording apparatus, electrode paste, alcohol swabs, rubber straps or disposable electrodes

BIOPAC® BSL System with BSL software version 3.7.5 to 3.7.7 (for Windows 7/Vista/XP or Mac OS X 10.4-10.6), data acquisition unit MP36/35 or MP45, PC or Mac computer, Biopac Student Lab electrode lead set, disposable vinyl electrodes.

Instructors using the MP36/35/30 data acquisition unit with BSL software versions earlier than 3.7.5 (for Windows or Mac) will need slightly different channel settings and collection strategies. Instructions for using

Text continues on next page. →

* ***Note:*** *Instructions for using PowerLab® equipment can be found on MasteringA&P.*

MasteringA&P®

For related exercise study tools, go to the Study Area of **MasteringA&P.** There you will find:

- Practice Anatomy Lab PAL
- PhysioEx PEx
- A&PFlix A&PFlix
- Practice quizzes, Histology Atlas, eText, Videos, and more!

Pre-Lab Quiz

1. Circle True or False. Cardiac muscle cells are electrically connected by gap junctions and behave as a single unit.
2. Because it sets the rate of depolarization for the normal heart, the _____ node is known as the pacemaker of the heart.
   a. atrioventricular **b.** Purkinje **c.** sinoatrial
3. Circle True or False. Stimulation by the nerves of the autonomic nervous system is essential for cardiac muscle to contract.
4. Today you will create a graphic recording of the electrical changes that occur during a cardiac cycle. This is known as an:
   a. electrocardiogram
   b. electroencephalogram
   c. electromyogram
5. Circle the correct underlined term. The typical ECG has three / six normally recognizable deflection waves.
6. In a typical ECG, the _____ wave signals the depolarization of the atria immediately before they contract.
   a. P **c.** R
   b. Q **d.** T
7. Circle True or False. The repolarization of the atria is usually masked by the large QRS complex.
8. Circle the correct underlined term. A heart rate over 100 beats/minute is known as tachycardia / bradycardia.
9. How many electrodes will you place on your subject for today's activity if you use a standard ECG apparatus?
   a. 3 **c.** 10
   b. 4 **d.** 12
10. Circle True or False. ECG can be used to calculate heart rate.

the older data acquisition unit can be found on MasteringA&P.

- Cot or lab table; pillow (optional)
- Millimeter ruler

Heart contraction results from a series of depolarization waves that travel through the heart preliminary to each beat. Because cardiac muscle cells are electrically connected by gap junctions, the entire myocardium behaves like a single unit, a **functional syncytium.**

The Intrinsic Conduction System

The ability of cardiac muscle to beat is intrinsic—it does not depend on impulses from the nervous system to initiate its contraction and will continue to contract rhythmically even if all nerve connections are severed. The **intrinsic conduction system** of the heart consists of **cardiac pacemaker cells.** The intrinsic conduction system ensures that heart muscle depolarizes in an orderly and sequential manner, from atria to ventricles, and that the heart beats as a coordinated unit.

The components of the intrinsic conduction system include the **sinoatrial (SA) node,** located in the right atrium just inferior to the entrance to the superior vena cava; the **atrioventricular (AV) node** in the lower atrial septum at the junction of the atria and ventricles; the **AV bundle (bundle of His)** and right and left **bundle branches,** located in the interventricular septum; and the **subendocardial conducting network,** also called **Purkinje fibers** (**Figure 31.1**).

Note that the atria and ventricles are separated from one another by a region of electrically inert connective tissue, so the depolarization wave can be transmitted to the ventricles only via the tract between the AV node and AV bundle. Thus, any damage to the AV node-bundle pathway partially or totally insulates the ventricles from the influence of the SA node.

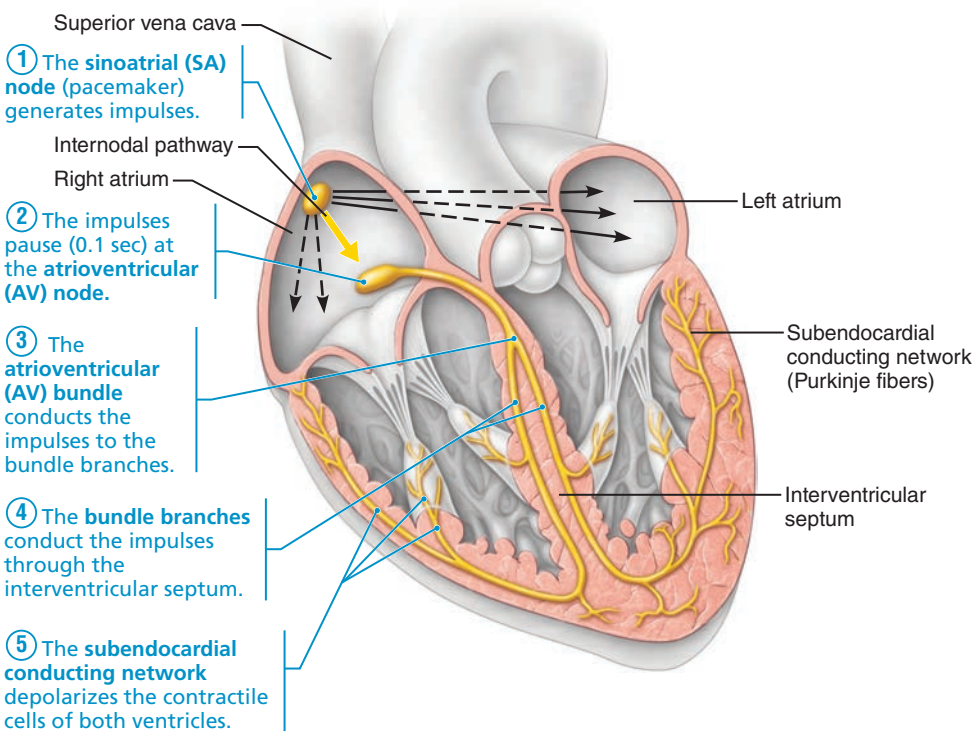
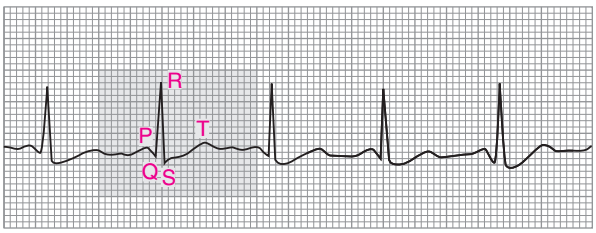


Figure 31.1 The intrinsic conduction system of the heart. Impulses travel through the heart in order ① to ⑤ following the yellow pathway. Dashed-line arrows indicate transmission of the impulse from the SA node through the atria. Solid yellow arrow indicates transmission of the impulse from the SA node to the AV node via the internodal pathway.

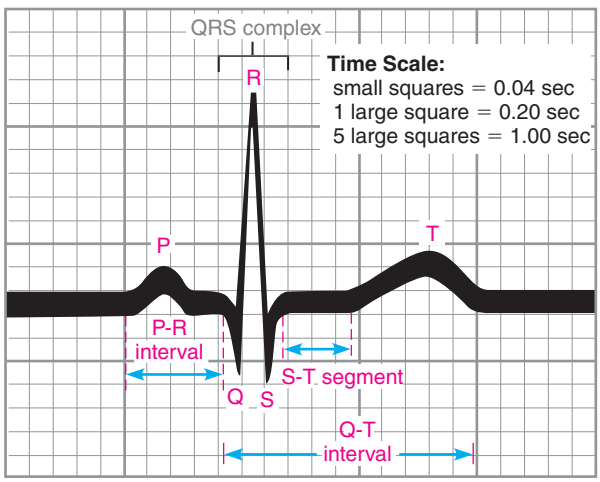
Electrocardiography

The conduction of impulses through the heart generates electrical currents that eventually spread throughout the body. These impulses can be detected on the body's surface and recorded with an instrument called an *electrocardiograph.* The graphic recording of the electrical changes occurring during the cardiac cycle is called an **electrocardiogram (ECG** or **EKG)** (**Figure 31.2**). A typical ECG has three recognizable deflection waves: the P wave, the QRS complex, and the T wave. For analysis, the ECG is divided into segments and intervals. A **segment** is a region between two waves. For example, the S-T segment is the region between the end of the S deflection and the start of the T wave. An **interval** is a region that contains a segment and one or more waves. For example, the Q-T interval includes the S-T segment as well as the QRS complex and the T wave. Boundaries for waves as well as some commonly measured segments and intervals are described in **Table 31.1**. The deflection waves of an ECG correlate to the depolarization and repolarization of the heart's chambers (**Figure 31.3**, p. 462).

Abnormalities of the deflection waves and changes in the time intervals of the ECG are useful in detecting myocardial infarcts (heart attacks) or problems with the conduction system of the heart.



(a)



(b)

Figure 31.2 The normal electrocardiogram. (a) Regular sinus rhythm. **(b)** Waves, segments, and intervals of a normal ECG.

Table 31.1 Boundaries of Each ECG Component

Feature	Boundaries
P wave	Start of P deflection to return to baseline
P-R interval	Start of P deflection to start of Q deflection
QRS complex	Start of Q deflection to S return to baseline
S-T segment	End of S deflection to start of T wave
Q-T interval	Start of Q deflection to end of T wave
T wave	Start of T deflection to return to baseline
T-P segment	End of T wave to start of next P wave
R-R interval	Peak of R wave to peak of next R wave

Table 31.2 summarizes some examples of abnormal electrocardiogram tracings and their possible clinical significance.

A heart rate over 100 beats/min is referred to as **tachycardia;** a rate below 60 beats/min is **bradycardia.** Although neither condition is pathological, prolonged tachycardia may progress to **fibrillation,** a condition of rapid uncoordinated heart contractions. Bradycardia in athletes is a positive finding; that is, it indicates an increased efficiency of cardiac functioning. Because *stroke volume* (the amount of blood ejected by a ventricle with each contraction) increases with physical conditioning, the heart can contract more slowly and still meet circulatory demands.

Twelve standard leads are used to record an ECG for diagnostic purposes. Three of these are bipolar leads that measure the voltage difference between the arms, or an arm and a leg, and nine are unipolar leads. Together the 12 leads provide a fairly comprehensive picture of the electrical activity of the heart.

For this investigation, four electrodes are used (**Figure 31.4**, p. 462), and results are obtained from the three *standard limb leads* (also shown in Figure 31.4). Several types of physiographs or ECG recorders are available. Your instructor will provide specific directions on how to set up and use the available

Table 31.2 Examples of Abnormal ECGs and Possible Clinical Significance

Finding	Possible clinical significance
Enlarged R wave	Enlarged ventricles.
Prolonged P-R interval	First-degree heart block. The signal from the SA node to the AV node is delayed longer than normal.
Prolonged Q-T interval (when compared to the R-R interval)	Increased risk of ventricular arrhythmias. This interval corresponds to the beginning of ventricular depolarization through ventricular repolarization.
S-T segment elevated from baseline	Myocardial infarction (heart attack).

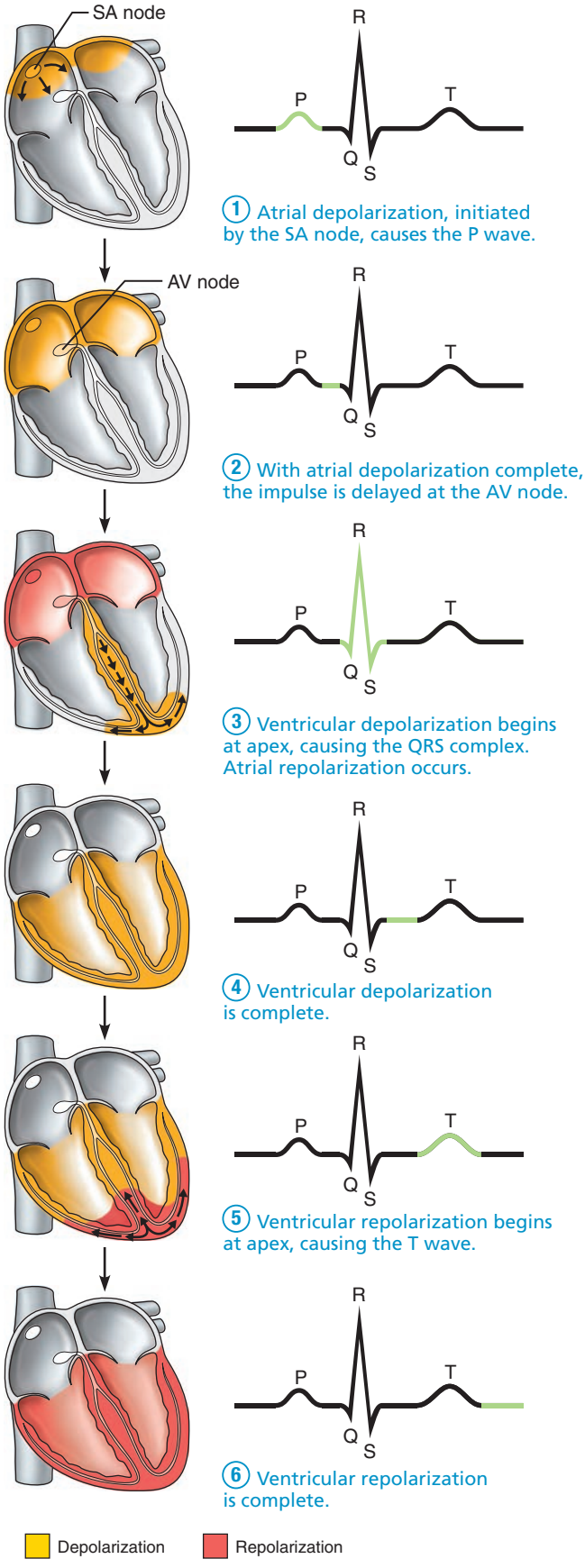


Figure 31.3 **The sequence of depolarization and repolarization of the heart related to the deflection waves of an ECG tracing.**

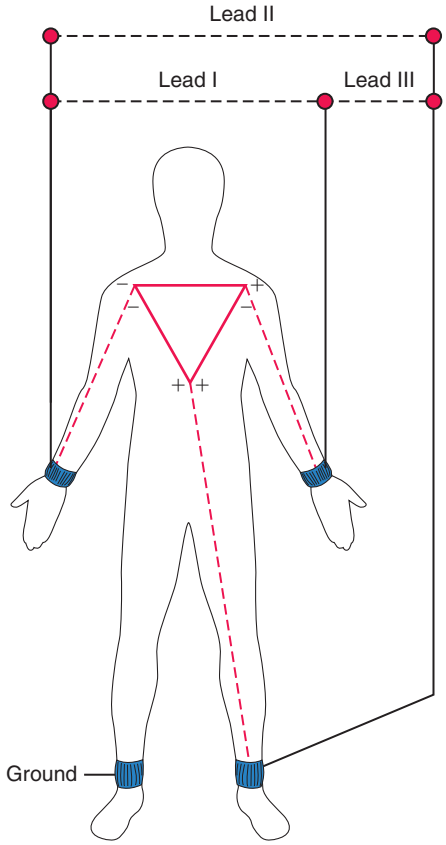


Figure 31.4 **ECG recording positions for the standard limb leads.**

Prepare for lab: Watch the Pre-Lab Video
MasteringA&P®>Study Area>Pre-Lab Videos

apparatus if standard ECG apparatus is used (Activity 1A). Instructions for use of BIOPAC® apparatus (Activity 1B) follow (pp. 464–468).

Understanding the Standard Limb Leads

As you might expect, electrical activity recorded by any lead depends on the location and orientation of the recording electrodes. Clinically, it is assumed that the heart lies in the center of a triangle with sides of equal lengths *(Einthoven's triangle)* and that the recording connections are made at the corners of that triangle. But in practice, the electrodes connected to each arm and to the left leg are considered to connect to the triangle corners. The standard limb leads record the voltages generated between any two of the connections. A recording using lead I (RA-LA), which connects the right arm (RA) and the left arm (LA), is most sensitive to electrical activity spreading horizontally across the heart. Lead II (RA-LL) and lead III (LA-LL) record activity along the vertical axis (from the base of the heart to its apex) but from different orientations. The significance of Einthoven's triangle is that the sum of the voltages of leads I and III equals that in lead II (Einthoven's law). Hence, if the voltages of two of the standard leads are recorded, that of the third lead can be determined mathematically.

Activity 1A

Recording ECGs Using a Standard ECG Apparatus

Preparing the Subject

1. If using electrodes that require gel, place the gel on four electrode plates and position each electrode as follows after scrubbing the skin at the attachment site with an alcohol swab. Attach an electrode to the anterior surface of each forearm, about 5 to 8 cm (2 to 3 in.) above the wrist, and secure them with rubber straps. In the same manner, attach an electrode to each leg, approximately 5 to 8 cm above the ankle. Disposable electrodes may be placed directly on the subject in the same areas.

2. Attach the appropriate tips of the patient cable to the electrodes. The cable leads are marked RA (right arm), LA (left arm), LL (left leg), and RL (right leg, the ground).

Making a Baseline Recording

1. Position the subject comfortably in a supine position on a cot, or sitting relaxed on a laboratory chair.

2. Turn on the power switch, and adjust the sensitivity knob to 1. Set the paper speed to 25 mm/sec and the lead selector to the position corresponding to recording from lead I (RA-LA).

3. Set the control knob at the **RUN** position and record the subject's at-rest ECG from lead I for 2 to 3 minutes or until the recording stabilizes. The subject should try to relax and not move unnecessarily, because the skeletal muscle action potentials will also be recorded.

4. Stop the recording and mark it "lead I."

5. Repeat the recording procedure for leads II (RA-LL) and III (LA-LL).

6. Each student should take a representative portion of one of the lead recordings and label the record with the name of the subject and the lead used. Identify and label the P, QRS, and T waves. The calculations you perform for your recording should be based on the following information: Because the paper speed was 25 mm/sec, each millimeter of paper corresponds to a time interval of 0.04 sec. Thus, if an interval requires 4 mm of paper, its duration is 4 mm × 0.04 sec/mm = 0.16 sec.

7. Calculate the heart rate. Obtain a millimeter ruler and measure the R to R interval. Enter this value into the following equation to find the time for one heartbeat.

_____ mm/beat × 0.04 sec/mm = _____ sec/beat

Now find the beats per minute, or heart rate, by using the figure just calculated for seconds per beat in the following equation:

60 sec/min ÷ (sec/beat) = beats/min

Measure the QRS complex, and calculate its duration.

_____

Measure the Q-T interval, and calculate its duration.

_____

Measure the P-R interval, and calculate its duration.

_____

Are the calculated values within normal limits?

_____

8. At the bottom of this page, attach sections of the ECG recordings from leads I through III. Make sure you indicate the paper speed, lead, and subject's name on each tracing. Also record the heart rate on the tracing.

WHY THIS MATTERS | **Atrial Fibrillation (AF)**

During atrial fibrillation, or AF, the atria spasm instead of contracting as a coordinated unit, which leads to pooling of blood in the atria. Atrial fibrillation is a result of damage to the intrinsic conduction system. During afib, the atria generate as many as 500 action potentials per minute, much faster than the usual 100 action potentials per minute generated by the SA node. Multiple signals flood the AV node, but it can't repolarize fast enough to pass on all of these action potentials. The rate of contraction of the ventricles may increase or decrease, contributing to the irregular, but often rapid, heartbeat. The underlying cause of AF is usually other heart conditions, such as hypertension and coronary heart disease. ■

Recording the ECG for Running in Place

1. Make sure the electrodes are securely attached to prevent electrode movement while recording the ECG.

2. Set the paper speed to 25 mm/sec, and prepare to make the recording using lead I.

3. Record the ECG while the subject is running in place for 3 minutes. Then have the subject sit down, but continue to record the ECG for an additional 4 minutes. *Mark the recording* at the end of the 3 minutes of running and at 1 minute after cessation of activity.

4. Stop the recording. Calculate the beats/min during the third minute of running, at 1 minute after exercise, and at 4 minutes after exercise. Record below:

_____ beats/min while running in place

_____ beats/min at 1 minute after exercise

_____ beats/min at 4 minutes after exercise

5. Compare this recording with the previous recording from lead I. Which intervals are shorter in the "running" recording?

_____

Text continues on next page. →

6. Does the subject's heart rate return to resting level by 4 minutes after exercise?

_____

Recording the ECG During Breath Holding

1. Position the subject comfortably in the sitting position.

2. Using lead I and a paper speed of 25 mm/sec, begin the recording. After approximately 10 seconds, instruct the subject to begin breath holding, and mark the record to indicate the onset of the 1-minute breath-holding interval.

3. Stop the recording after 1 minute, and remind the subject to breathe. Calculate the beats/minute during the 1-minute experimental (breath-holding) period.

Beats/min during breath holding: _____

4. Compare this recording with the lead I recording obtained under resting conditions.

What differences do you see? _____

_____

Attempt to explain the physiological reason for the differences you have seen. (Hint: A good place to start might be to check hypoventilation or the role of the respiratory system in acid-base balance of the blood.)

_____

_____

_____

_____

Activity 1B

Electrocardiography Using BIOPAC®

In this activity, you will record the electrical activity of the heart under three different conditions: (1) while the subject is lying down, (2) after the subject sits up and breathes normally, and (3) after the subject has exercised and is breathing deeply.

In order to obtain a clear ECG, it is important that the subject:

- Remain still during the recording.
- Refrain from laughing or talking during the recording.
- When in the sitting position, keep arms and legs steady and relaxed.
- Remove metal watches and bracelets.

Setting Up the Equipment

1. Connect the BIOPAC® unit to the computer and turn the computer **ON**.

2. Make sure the BIOPAC® unit is **OFF**.

3. Plug in the equipment (as shown in **Figure 31.5**):

- Electrode lead set—CH 1

4. Turn the BIOPAC® unit **ON**.

5. Place the three electrodes on the subject (as shown in **Figure 31.6**), and attach the electrode leads according to the colors indicated. The electrodes should be placed on the medial surface of each leg, 5 to 8 cm (2 to 3 in.) superior to the ankle. The other electrode should be placed on the right anterior forearm 5 to 8 cm above the wrist.

6. The subject should lie down and relax in a comfortable position with eyes closed. A chair or place to sit up should be available nearby.

7. Start the Biopac Student Lab program on the computer by double-clicking the icon on the desktop or by following your instructor's guidance.

8. Select lesson **L05-ECG-1** from the menu, and click **OK**.

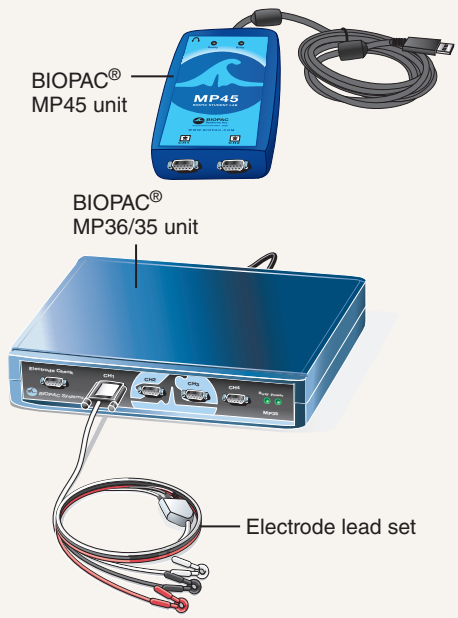


Figure 31.5 Setting up the BIOPAC® unit. Plug the electrode lead set into Channel 1. Leads are shown plugged into the MP36/35 unit.

9. Type in a filename that will save this subject's data on the computer hard drive. You may want to use the subject's last name followed by ECG-1 (for example, SmithECG-1), then click **OK**.

10. Because we are not recording all available lesson options, click the File Menu, choose **Lesson Preferences,** choose **Heart Rate Data,** and click **OK.** Choose **Do Not Calculate** and click **OK.** Click the file menu and choose **Lesson Preferences** again; select **Lesson Segments** and click **OK**; click the box for **Deep Breathing** to deselect it; and then click **OK.**

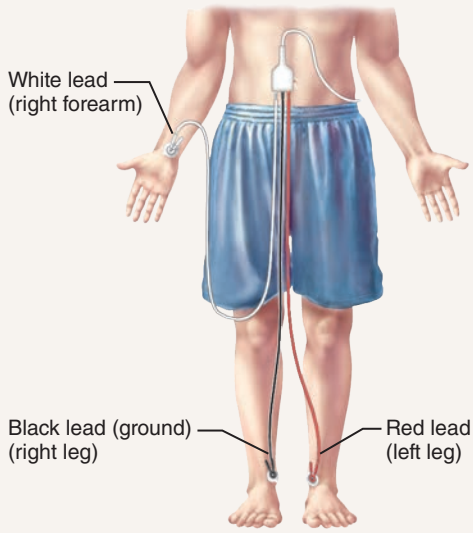


Figure 31.6 Placement of electrodes and the appropriate attachment of electrode leads by color.

Calibrating the Equipment

- Examine the electrodes and the electrode leads to be certain they are properly attached.

1. The subject must remain supine, still, and relaxed. With the subject in a still position, click **Calibrate.** This will initiate the process whereby the computer will automatically establish parameters to record the data.

2. The calibration procedure will stop automatically after 8 seconds.

3. Observe the recording of the calibration data, which should look similar to the data example (**Figure 31.7**).

- If the data look very different, click **Redo Calibration** and repeat the steps above.
- If the data look similar, proceed to the next section. *Don't* click **Done** until you have completed all 3 segments.

Recording Segment 1: Subject Lying Down

1. To prepare for the recording, remind the subject to remain still and relaxed while lying down.

2. Click **Continue** and when prepared, click **Record** and gather data for 20 seconds. At the end of 20 seconds, click **Suspend.**

3. Observe the data, which should look similar to the data example (**Figure 31.8**).

- If the data look very different, click **Redo** and repeat the steps above. Be certain to check attachment of the electrodes and leads, and remind the subject not to move, talk, or laugh.
- If the data look similar, move on to the next recording segment.

Recording Segment 2: After Subject Sits Up, with Normal Breathing

1. Tell the subject to be ready to sit up in the designated location. With the exception of breathing, the subject should try to remain motionless after assuming the seated position. *If the subject moves too much during recording after sitting up, unwanted skeletal muscle artifacts will affect the recording.*

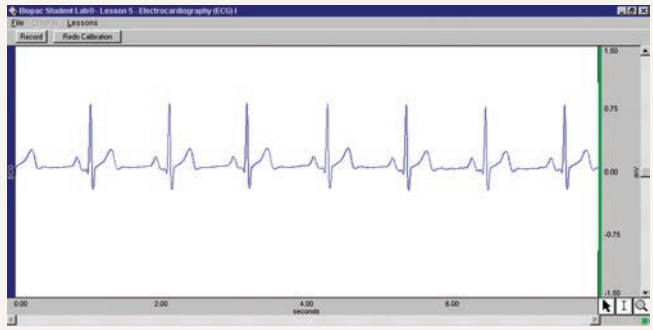


Figure 31.7 Example of calibration data.

2. Click **Continue** and when prepared, instruct the subject to sit up. Immediately after the subject assumes a motionless state, click **Record,** and the data will begin recording.

3. At the end of 20 seconds, click **Suspend** to stop recording.

4. Observe the data, which should look similar to the data example (**Figure 31.9**, p. 466).

- If the data look very different, have the subject lie down, then click **Redo.** Be certain to check attachment of the electrodes, then repeat steps 1–4 above. Do not click **Record** until the subject is motionless.
- If the data look similar, move on to the next recording segment.

Recording Segment 3: After Subject Exercises, with Deep Breathing

1. Click **Continue,** but *don't* click **Record** until after the subject has exercised. Remove the electrode pinch connectors from the electrodes on the subject.

2. Have the subject do a brief round of exercise, such as jumping jacks or running in place for 1 minute, in order to elevate the heart rate.

3. As quickly as possible after the exercise, have the subject resume a motionless, seated position. Reattach the pinch

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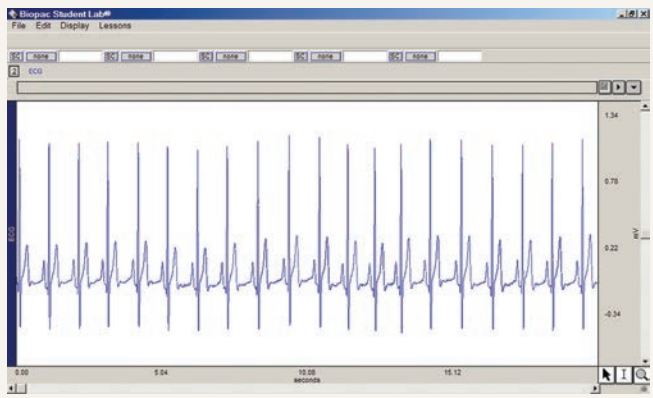

Figure 31.8 Example of ECG data while the subject is lying down.

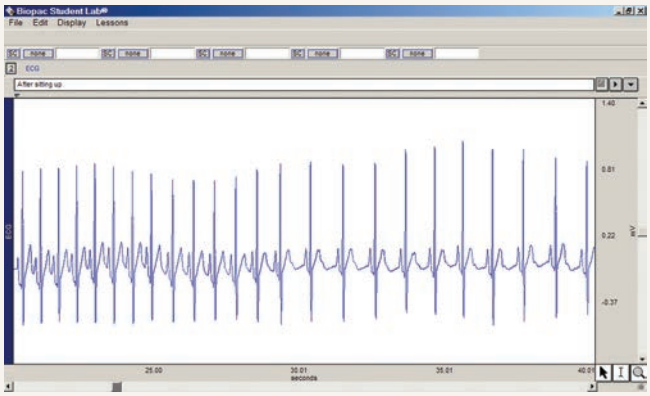

Figure 31.9 Example of ECG data after the subject sits up and breathes normally.

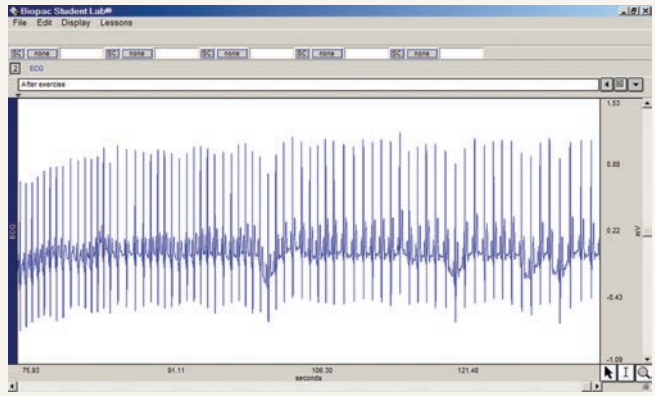

Figure 31.10 Example of ECG data after the subject exercises.

connectors. Once again, if the subject moves too much during recording, unwanted skeletal muscle artifacts will affect the data. After exercise, the subject is likely to be breathing deeply but otherwise should remain as still as possible.

4. Immediately after the subject assumes a motionless, seated state, click **Record,** and the data will begin recording. Record the ECG for 60 seconds in order to observe post-exercise recovery.

5. After 60 seconds, click **Suspend** to stop recording.

6. Observe the data, which should look similar to the data example (**Figure 31.10**).

- If the data look very different, click **Redo** and repeat the steps above. Be certain to check attachment of the electrodes and leads, and remember not to click **Record** until the subject is motionless.

7. When finished, click **Done** and then **Yes.** Remove the electrodes from the subject.

8. A pop-up window will appear. To record from another subject, select **Record from another subject** and return to step 5 under Setting Up the Equipment. If continuing to the Data Analysis section, select **Analyze current data file** and proceed to step 2 of the Data Analysis section.

Data Analysis

1. If just starting the BIOPAC® program to perform data analysis, enter **Review Saved Data** mode and choose the file with the subject's ECG data (for example, SmithECG-1).

2. Use the following tools to adjust the data in order to clearly view and analyze four consecutive cardiac cycles:

- Click the magnifying glass (near the I-beam cursor box) to activate the **zoom** function. Use the magnifying glass cursor to click on the very first waveforms until there are about 4 seconds of data represented (see horizontal time scale at the bottom of the screen).
- Select the **Display** menu at the top of the screen, and click **Autoscale Waveforms** (or click Ctrl + Y). This function will adjust the data for better viewing.
- Click the **Adjust Baseline** button. Two new buttons will appear; simply click these buttons to move the waveforms **Up** or **Down** so they appear clearly in the center of the display window. Once they are centered, click **Exit.**

3. Note that the first two pairs of channel/measurement boxes at the top of the screen are set to Delta T and bpm.

Channel	Measurement	Data
CH 1	Delta T	ECG
CH 1	bpm	ECG

Analysis of Segment 1: Subject Lying Down

1. Use the arrow cursor and click the I-beam cursor box for the "area selection" function.

2. First measure **Delta T** and **bpm** in Segment 1 (approximately seconds 0–20). Using the I-beam cursor, highlight from the peak of one R wave to the peak of the next R wave (as shown in **Figure 31.11**).

3. Observe that the computer automatically calculates the **Delta T** and **bpm** for the selected area. These measurements represent the following:

Delta T (difference in time): Computes the elapsed time between the beginning and end of the highlighted area

bpm (beats per minute): Computes the beats per minute when the area from the R wave of one cycle to the R wave of another cycle is highlighted

4. Record these data in the **Segment 1 Samples chart** under R to R Sample 1 (round to the nearest 0.01 second and 0.1 beat per minute).

5. Using the I-beam cursor, highlight two other pairs of R to R areas in this segment. Record the data in the same chart under Samples 2 and 3.

6. Calculate the means of the data in this chart.

7. Next, use the **zoom, Autoscale Waveforms,** and **Adjust Baseline** tools described in step 2 to focus in on one ECG waveform within Segment 1. (See the example in **Figure 31.12**).

8. Once a single ECG waveform is centered for analysis, click the I-beam cursor box to activate the "area selection" function.

9. Using the highlighting function and **Delta T** computation, measure the duration of every component of the

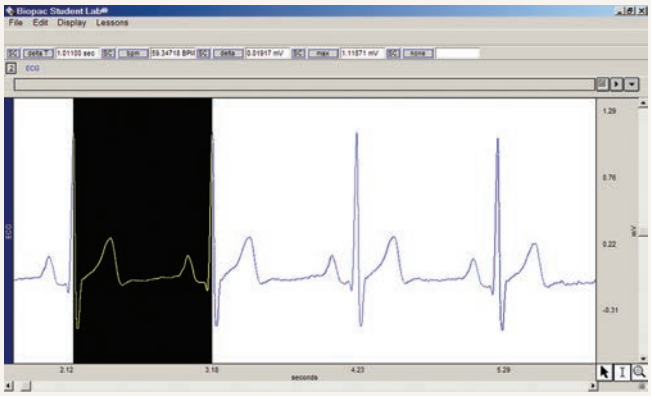

Figure 31.11 Example of highlighting from R wave to R wave.

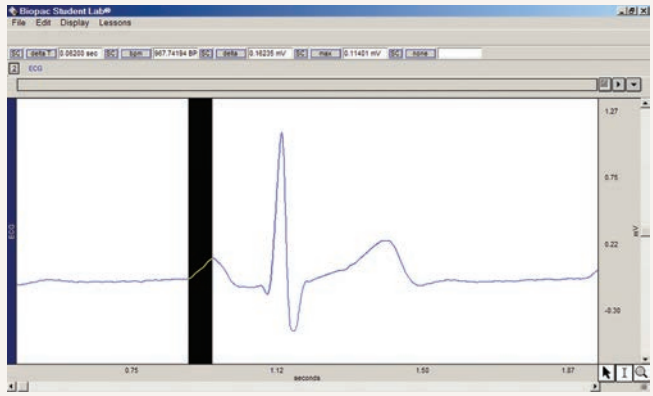

Figure 31.12 Example of a single ECG waveform with the first part of the P wave highlighted.

Segment 1 Samples for Delta T and bpm					
Measure	**Channel**	**R to R Sample 1**	**R to R Sample 2**	**R to R Sample 3**	**Mean**
Delta T	CH 1				
bpm	CH 1				

ECG waveform. (Refer to Figure 31.2b and Table 31.1 for guidance in highlighting each component.)

10. Highlight each component of one cycle. Observe the elapsed time, and record this data under Cycle 1 in the **Segment 1 Elapsed Time chart**.

11. Scroll along the horizontal axis at the bottom of the data to view and analyze two additional cycles in Segment 1. Record the elapsed time for every component of Cycle 2 and Cycle 3 in the Segment 1 Elapsed Time chart.

12. In the same chart, calculate the means for the three cycles of data and record.

Analysis of Segment 2: Subject Sitting Up and Breathing Normally

1. Scroll along the horizontal time bar until you reach the data for Segment 2 (approximately seconds 20–40). A marker with "Seated" should denote the beginning of this data.

2. As in the analysis of Segment 1, use the I-beam tool to highlight and measure the **Delta T** and **bpm** between three different pairs of R waves in this segment, and record the data in the **Segment 2 Samples chart** on p. 468.

Analysis of Segment 3: After Exercise with Deep Breathing

1. Scroll along the horizontal time bar until you reach the data for Segment 3 (approximately seconds 40–100). A marker with "After exercise" should denote the beginning of this data.

2. As before, use the I-beam tool to highlight and measure the **Delta T** and **bpm** between three pairs of R waves in this segment, and record the data in the **Segment 3 Samples chart** on p. 468.

Segment 1 Elapsed Time for ECG Components (seconds)				
Component	**Cycle 1**	**Cycle 2**	**Cycle 3**	**Mean**
P wave				
P-R interval				
QRS complex				
S-T segment				
Q-T interval				
T wave				
T-P segment				
R-R interval				

3. Using the instructions for steps 7–9 in the section Analysis of Segment 1, highlight and observe the elapsed time for each component of one cycle, and record these data under Cycle 1 in the **Segment 3 Elapsed Time chart** on p. 468.

4. When finished, **Exit** from the file menu to quit.

Compare the average **Delta T** times and average **bpm** between the data in Segment 1 (lying down) and the data in Segment 3 (after exercise). Which is greater in each case?

Text continues on next page. →

Segment 2 Samples for Delta T and bpm					
Measure	**Channel**	**R to R Sample 1**	**R to R Sample 2**	**R to R Sample 3**	**Mean**
Delta T	CH 1				
bpm	CH 1				

Segment 3 Samples for Delta T and bpm					
Measure	**Channel**	**R to R Sample 1**	**R to R Sample 2**	**R to R Sample 3**	**Mean**
Delta T	CH 1				
bpm	CH 1				

What is the relationship between the elapsed time **(Delta T)** between R waves and the heart rate?

What event does the period between R waves correspond to?

Is there a change in heart rate when the subject makes the transition from lying down (Segment 1) to a sitting position (Segment 2)?

Examine the average duration of each of the ECG components in Segment 1 and the data in Segment 3. In the **Average Duration chart**, record the average values for Segment 1 and the data for Segment 3. Draw a circle around those measures that fit within the normal range.

Compare the Q-T intervals in the data while the subject is at rest versus after exercise; this interval corresponds closely to the duration of contraction of the ventricles. Describe and explain any difference.

Compare the duration in the period from the end of each T wave to the next P wave while the subject is at rest versus after exercise. Describe and explain any difference.

A patient presents with a P-R interval three times longer than the normal duration. What might be the cause of this abnormality?

Segment 3 Elapsed Time for ECG Components (seconds)	
Component	**Cycle 1**
P wave	
P-R interval	
QRS complex	
S-T segment	
Q-T interval	
T wave	
T-P segment	
R-R interval	

Average Duration for ECG Components			
ECG component	**Normal duration (seconds)**	**Segment 1 (lying down)**	**Segment 3 (post-exercise)**
P wave	0.07–0.18		
P-R interval	0.12–0.20		
QRS complex	0.06–0.12		
S-T segment	<0.20		
Q-T interval	0.32–0.38		
T wave	0.10–0.25		
T-P segment	0–0.40		
R-R interval	varies		

EXERCISE 31

REVIEW SHEET

Conduction System of the Heart and Electrocardiography

Name _____ Lab Time/Date _____

The Intrinsic Conduction System

1. List the elements of the intrinsic conduction system in order, starting from the SA node.

   SA node → _____ → _____ →

   _____ → _____

   At what structure in the transmission sequence is the impulse temporarily delayed? _____

   Why? _____

   _____

2. Even though cardiac muscle has an inherent ability to beat, the intrinsic conduction system plays a critical role in heart physiology.

   What is that role? _____

   _____

Electrocardiography

3. Define *ECG.* _____

   _____

4. Draw an ECG wave form representing one heartbeat. Label the P wave, QRS complex, and T wave; the P-R interval; the S-T segment, and the Q-T interval.

5. Why does heart rate increase during running? _____

   _____

   _____

6. Describe what happens in the cardiac cycle in the following situations.

   1. immediately before the P wave: _____
   2. during the P wave: _____
   3. immediately after the P wave: _____
   4. during the QRS complex: _____
   5. immediately after the QRS complex (S-T segment): _____
   6. during the T wave: _____

7. Define the following terms.

   1. *tachycardia:* _____
   2. *bradycardia:* _____
   3. *fibrillation:* _____

8. Abnormalities of heart valves can be detected more accurately by auscultation than by electrocardiography. Why is this so?

_____

_____

_____

WHY THIS MATTERS

9. Given what you know about the correlation between the ECG waves and the electrical events in the heart, what wave of the ECG tracing would you expect to be affected in atrial fibrillation? Explain.

_____

10. Which is more serious, atrial fibrillation or ventricular fibrillation? _____

    Why? _____