

LESSON

2-1

Introduction to Hematology

LESSON OBJECTIVES

After studying this lesson, the student will:

- Discuss the origin of blood cells.
- Explain the differences among veins, arteries, and capillaries.
- List five plasma components.
- Name the three types of formed elements of blood and state the function of each.
- Name the five types of white blood cells.
- Name the preferred specimens for most hematology tests.
- Name eight tests that are included in the complete blood count (CBC).
- Explain safety precautions that must be observed in the hematology laboratory.
- Explain how quality assessment (QA) procedures in hematology differ from QA in other laboratory departments, such as clinical chemistry.
- Name two inherited hematological diseases.
- Explain what a secondary or acquired hematological disease is.
- Discuss why stem cells may be useful in treating disease.
- Define the glossary terms.

GLOSSARY

anemia / a condition in which the red blood cell count or hemoglobin level is below normal; a condition resulting in decreased oxygen-carrying capacity of the blood

anticoagulant / a chemical that prevents blood coagulation

artery / a blood vessel that carries oxygenated blood from the heart to the tissues

capillary / a minute blood vessel that connects the smallest arteries to the smallest veins and serves as an oxygen exchange vessel

cardiopulmonary circulation / the system of blood vessels that circulates blood from the heart to the lungs and back to the heart

CBC / complete blood count; a commonly performed group of hematological tests

deoxyhemoglobin / the hemoglobin formed when oxyhemoglobin releases oxygen to tissues

EDTA / ethylenediaminetetraacetic acid; an anticoagulant commonly used in hematology

erythrocyte / see red blood cell

granulocyte / a white blood cell containing granules in the cytoplasm; any of the neutrophilic, eosinophilic, or basophilic leukocytes

- hematology / the study of blood and blood-forming tissues
- hematopoietic stem cell / see hemopoietic stem cell
- hemoglobin (Hb, Hgb) / the major functional component of red blood cells that is the oxygen-carrying protein
- hemopoiesis / the process of blood cell formation and development; hematopoiesis
- hemopoietic stem cell / an undifferentiated bone marrow cell that gives rise to blood cells
- hemostasis / the process of stopping bleeding, which includes clot formation and clot dissolution
- leukemia / a chronic or acute disease involving unrestrained growth of leukocytes
- leukocyte / see white blood cell
- megakaryocyte / a large bone marrow cell from which platelets are derived
- oxyhemoglobin / the form of hemoglobin that binds and transports oxygen
- plasma / the liquid portion of blood in which blood cells are suspended
- platelet / a formed element in circulating blood that plays an important role in blood coagulation; a small disk-shaped fragment of cytoplasm derived from a megakaryocyte; a thrombocyte
- red blood cell (RBC) / blood cell that transports oxygen (O_2) to tissues and carbon dioxide (CO_2) to the lungs; erythrocyte
- stem cell / an undifferentiated cell
- systemic circulation / the system of blood vessels that carries blood from the heart to the tissues and back to the heart
- thrombocyte / a blood platelet
- vein / a blood vessel that carries deoxygenated blood from the tissues to the heart
- white blood cell (WBC) / blood cell that functions in immunity; leukocyte

INTRODUCTION

Hematology is the branch of medicine concerned primarily with studying the formed elements of blood (blood cells) and the blood-forming tissues. The formed elements of blood, red blood cells, white blood cells, and platelets, are examined in the hematology laboratory. The tests may be qualitative, such as observing and recording blood cell morphology, or quantitative, such as performing leukocyte or erythrocyte counts or determining the hematocrit. The study of hemostasis, the process of stopping bleeding, which includes both clot formation (coagulation) and clot dissolution (fibrinolysis), is included in hematology.

Hematological tests can give important information about a patient's general well-being. The hematology laboratory also performs tests to detect and monitor treatment of anemias, leukemias, and inherited blood disorders such as hemophilia and sickle cell anemia. The effects of radiation or chemotherapy treatments for cancer can also be monitored using hematological tests.

BLOOD VESSELS AND BLOOD CIRCULATION

The Circulatory System

The circulatory system performs several vital functions, including delivery of oxygen (O_2), nutrients, water, and hormones to tissues and cells; removal of carbon dioxide (CO_2) and other waste products from tissues and cells; regulation of body temperature; and protection against infection. These functions are carried out by the *blood*, the fluid that circulates through the vessels of the circulatory system and bathes the tissues.

In the cardiopulmonary circulation, blood circulates from the heart to the lungs and back to the heart. Oxygen exchange occurs in the lungs when O_2 is picked up by the blood and CO_2 is released (Figure 2-1). In the systemic circulation, blood is carried from the heart to the tissues and back to the heart, providing O_2 to tissues and cells in exchange for CO_2 , a waste product (Figure 2-2).

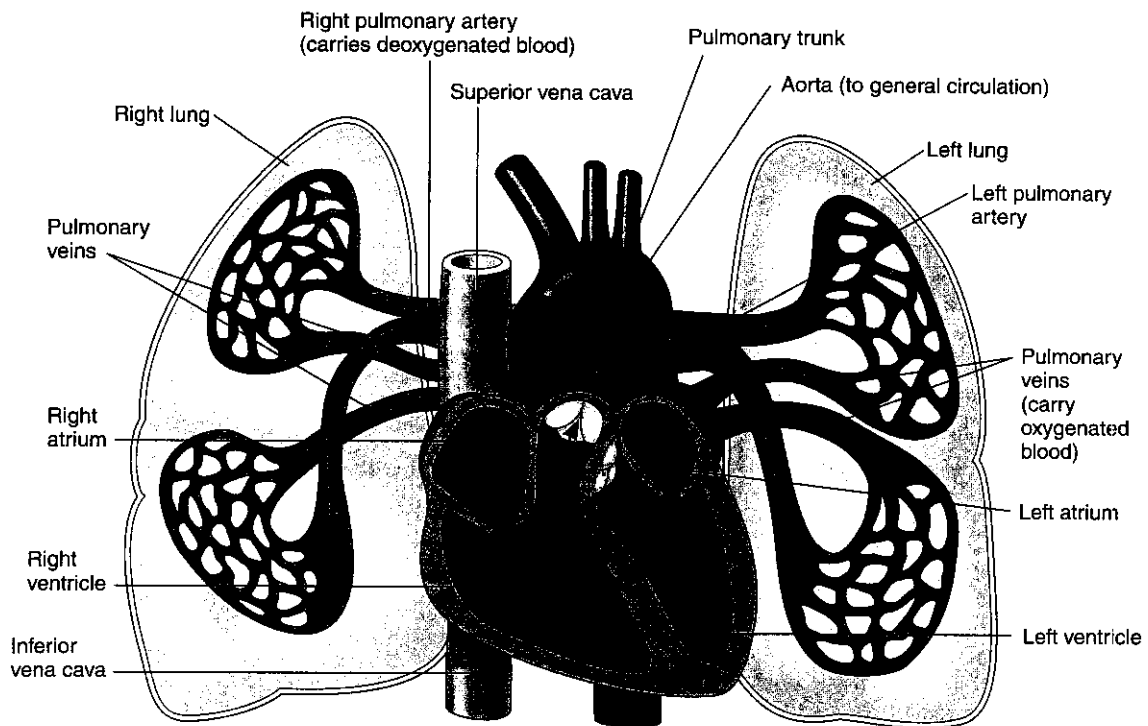


FIGURE 2-1 Diagram of cardiopulmonary circulation

Types of Blood Vessels

Blood is circulated by three major types of vessels: arteries, capillaries, and veins. There are about 60,000 miles of blood vessels in an average adult human. In general, arteries carry oxygenated blood and veins carry deoxygenated blood.

Arteries are thick-walled, elastic, and muscular and are the strongest type of blood vessel (Figure 2-2). The aorta is the largest artery in the body. Blood flows from the heart through the aorta into a series of successively smaller arteries and arterioles (small arteries) that eventually diverge to form a network of capillaries (Figure 2-3).

Capillaries are the smallest of the blood vessels and connect the smallest arterioles with the smallest veins called venules (Figure 2-3). Capillaries have thin walls allowing fluid, nutrients, and waste products to easily pass through these walls to or from the tissue cells. Because capillary beds are the site of O_2 - CO_2 exchange, both oxygenated and deoxygenated blood are present.

Veins carry deoxygenated blood from the capillaries to the heart. Capillaries expand into venules and then into veins that eventually converge to larger and larger vessels and form the largest vein, the vena cava. The walls of veins are not as thick, muscular, or elastic as those of arteries (Figure 2-2). Veins have valves that allow blood flow in only one direction—toward the heart.

COMPOSITION OF BLOOD

Blood makes up 6% to 8% of total body weight. A normal adult's blood volume is approximately 5 L, or 10 times the volume of a blood donor unit. Blood is composed of cellular elements sus-

pending in a fluid, plasma. About 50% to 60% of blood volume is plasma; the rest is mostly red blood cells.

Plasma

Plasma is a complex solution in which the blood cells are suspended (Figure 2-4). Plasma is more than 90% water; the remainder is dissolved solids such as proteins, lipids, carbohydrates, amino acids, antibodies, hormones, and electrolytes. Most of these substances are measured in the clinical chemistry department. Plasma also contains fibrinogen and the other blood-coagulation proteins necessary for normal blood clotting. The proteins involved in prevention of unwanted clotting and dissolution of formed clots are also present in the plasma.

Cellular Elements of Blood

The cellular elements of blood are commonly called blood cells. These include red blood cells, or erythrocytes; white blood cells, or leukocytes; and platelets, also called thrombocytes (Figure 2-5). Most hematology tests are designed to evaluate or measure a characteristic or function of one or more of the three blood cell types.

Red Blood Cells

Red blood cells are the most numerous blood cells (Figure 2-5). Each microliter (μ L) of blood contains approximately 5 million red blood cells; that means one drop of blood contains about 250 million red cells! Red blood cells live an average of 120 days in the circulation and remain in the circulatory system's vessels for their entire life span.

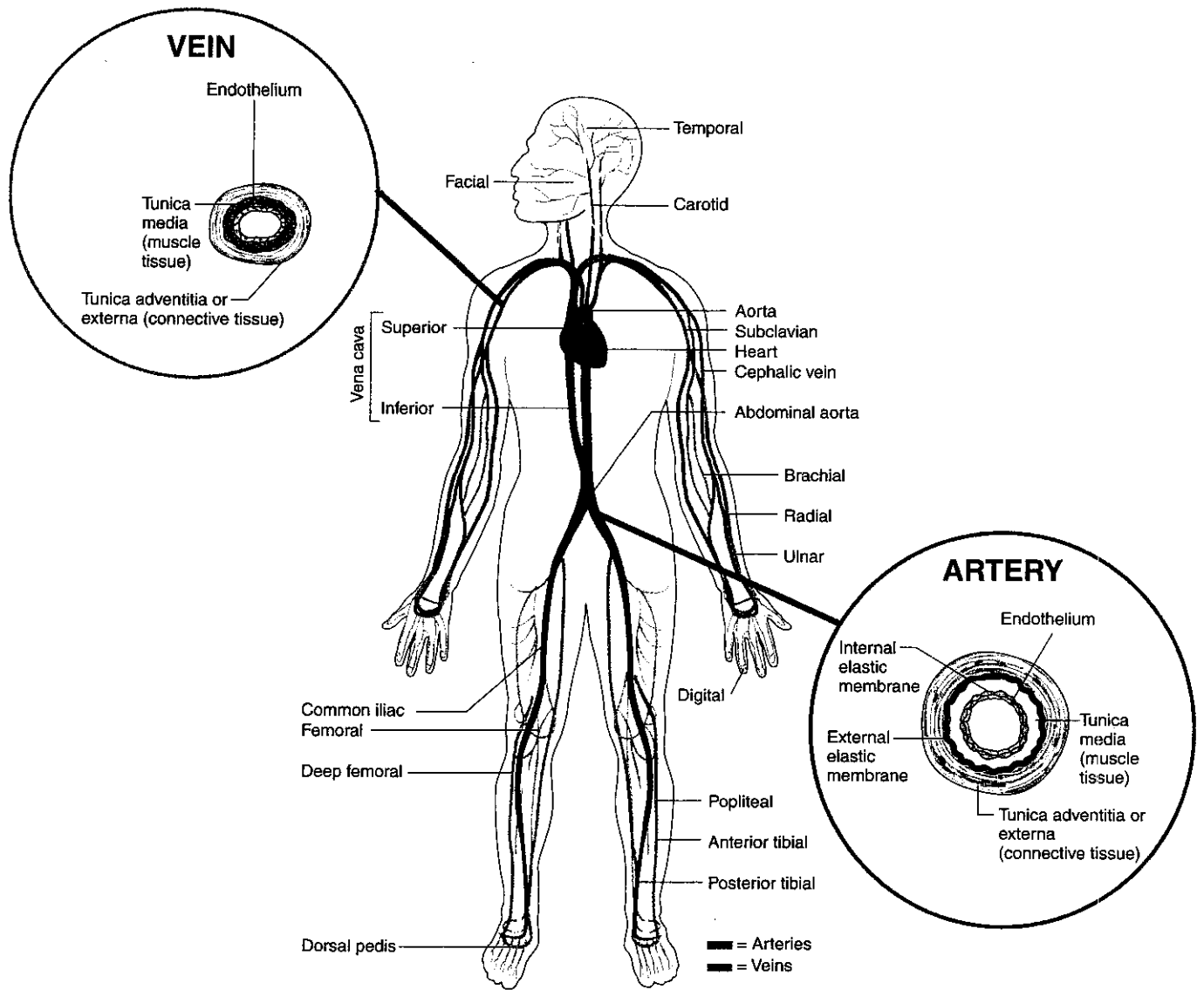


FIGURE 2-2 Systemic circulation showing the differences in the structure of veins and arteries

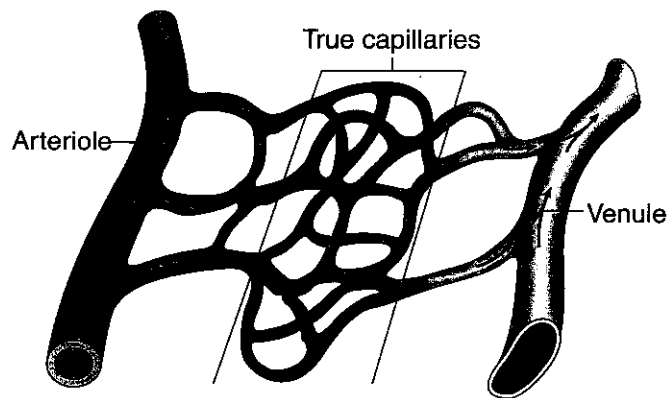
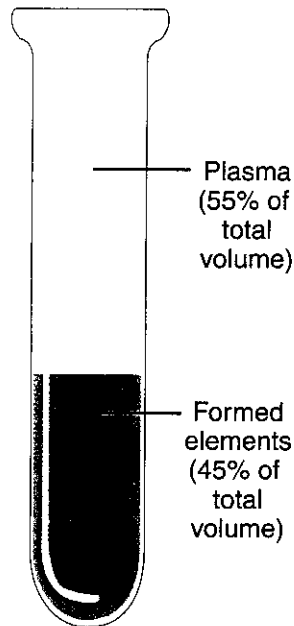


FIGURE 2-3 Capillary bed connecting an arteriole with a venule

The main function of red blood cells is to transport O₂ to the tissues and CO₂ to the lungs. This is actually performed by hemoglobin molecules, the major component of erythrocytes. Hemoglobin gives blood its red color. Arterial blood is bright red because of the oxyhemoglobin, hemoglobin that has bound O₂. Venous blood is dark red because of the presence of deoxyhemoglobin, hemoglobin that has released O₂.



Test tube containing whole blood

FIGURE 2-4 Diagram of a tube of blood showing separation of formed elements from plasma

White Blood Cells

White blood cells are the least numerous blood cells (Figure 2-5). Approximately 5,000 to 10,000 white blood cells are in each microliter of blood, or 5.0 to $10.0 \times 10^9/L$.

Five types of white blood cells are present in normal blood: *neutrophils*, *basophils*, *eosinophils*, *lymphocytes*, and *monocytes*. The neutrophils, basophils, and eosinophils are called granulocytes because of granules present in the cell cytoplasm.

White blood cells have varied life spans, from a few days to several years. Each type of white cell has unique functions, but all are associated with immunity or defense from infection. White blood cells perform most of their functions in the tissues. White blood cells use blood as a means of transport from one part of the body to another.

Platelets

Platelets, or thrombocytes, are not actually whole cells but are fragments of cytoplasm that have been released into circulating blood from large cells in the bone marrow (Figure 2-5). These large bone marrow cells are called megakaryocytes. Platelets average about 200,000 per microliter of blood and remain in the bloodstream about 10 days.

Platelets are important in several stages of hemostasis. They help stop bleeding by forming a plug in injured or damaged vessel walls. They also release chemicals or enzymes that are important in another stage of hemostasis, the coagulation cascade.

ORIGIN OF BLOOD CELLS

Hemopoiesis (hematopoiesis) is the formation and development of blood cells. In the young fetus, blood cells are made in the fetal liver. As the fetus develops, the bone marrow begins to take over this func-



White Blood Cell (Leukocyte)



Red Blood Cells (Erythrocytes)



Platelets (Thrombocytes)

	White Blood Cell (Leukocyte)	Red Blood Cells (Erythrocytes)	Platelets (Thrombocytes)
Function	Body defense (extravascular)	Transport of oxygen and carbon dioxide (intravascular)	Stoppage of bleeding
Formation	Bone marrow, lymphatic tissue	Bone marrow	Bone marrow
Size	9–18 micrometers	6–8 micrometers	1–4 micrometers
Shape	Nuclear shape varies	Biconcave disc	Varied
Life span	Varies, 24 hours–years	100–120 days	8–12 days
Numbers	4,500–11,000/microliter	4–6 million/microliter	150,000–400,000/microliter

FIGURE 2-5 Characteristics of red blood cells, white blood cells, and platelets

tion. In adults, most of the cellular elements of blood are produced in the bone marrow. Lymphocytes are produced not only in bone marrow but also in secondary lymphoid tissue such as the spleen and lymph nodes. After a period of development and maturation in the bone marrow, mature blood cells are released into the circulating blood, where they function in respiration (erythrocytes), immunity (leukocytes), and hemostasis (platelets). (See Figure 2-6.)

Blood cells require the same basic growth factors for their synthesis as other cell types. In addition, because red blood cells are very specialized, they require iron, vitamin B₁₂, and folic acid for proper formation and maturation.

Blood cells are continuously produced throughout an individual's life. All blood cells are derived from an undifferentiated bone marrow cell called the hemopoietic, or hematopoietic, stem cell. These cells continuously replicate and differentiate into all of the blood cell types, thus replenishing the body's blood cells.

The presence of stem cells in bone marrow is the basis for using bone marrow transplants to treat hematological disorders, such as leukemia and aplastic anemia, and to combat the damaging effects of cancer chemotherapy on blood cell production. The discovery that newborns' umbilical cords are rich in stem cells has provided an additional donor source of stem cells. Because cord blood is routinely collected when the umbilical cord is cut at birth, it is now possible to harvest these cells and use them as substitutes for bone marrow transplants.

HEMATOLOGICAL DISEASES

Many diseases involve primarily the blood cells. Some of these diseases are caused by improper or insufficient production of a cell type. For instance, in leukemia, white cell production is out of control and too many cells are produced. In anemia, red cell numbers are too low, which could be due to decreased red cell production, such as might be seen when a person has an iron deficiency. Anemia can also result when blood loss is more rapid than blood production by the bone marrow, as when a person has a bleeding ulcer. *Thrombocytopenia*, or low platelet count, which can be caused by viral infections or drug interactions, can result in bleeding tendencies.

Hematological diseases can also be due to defective cell function. Often, a disease can be due to a combination of improper cell production and defective function, as with most anemias and leukemias. For example, in iron-deficiency anemia, the patient has too few red blood cells and these function improperly because they do not contain enough hemoglobin. This causes fatigue, pallor, and shortness of breath, typical symptoms of anemia caused by decreased O₂ available to the tissues. In leukemia, although the patient has many leukocytes, the cells have not matured properly and cannot provide immunity. The patient may then be highly susceptible to infections, even though the WBC count is high.

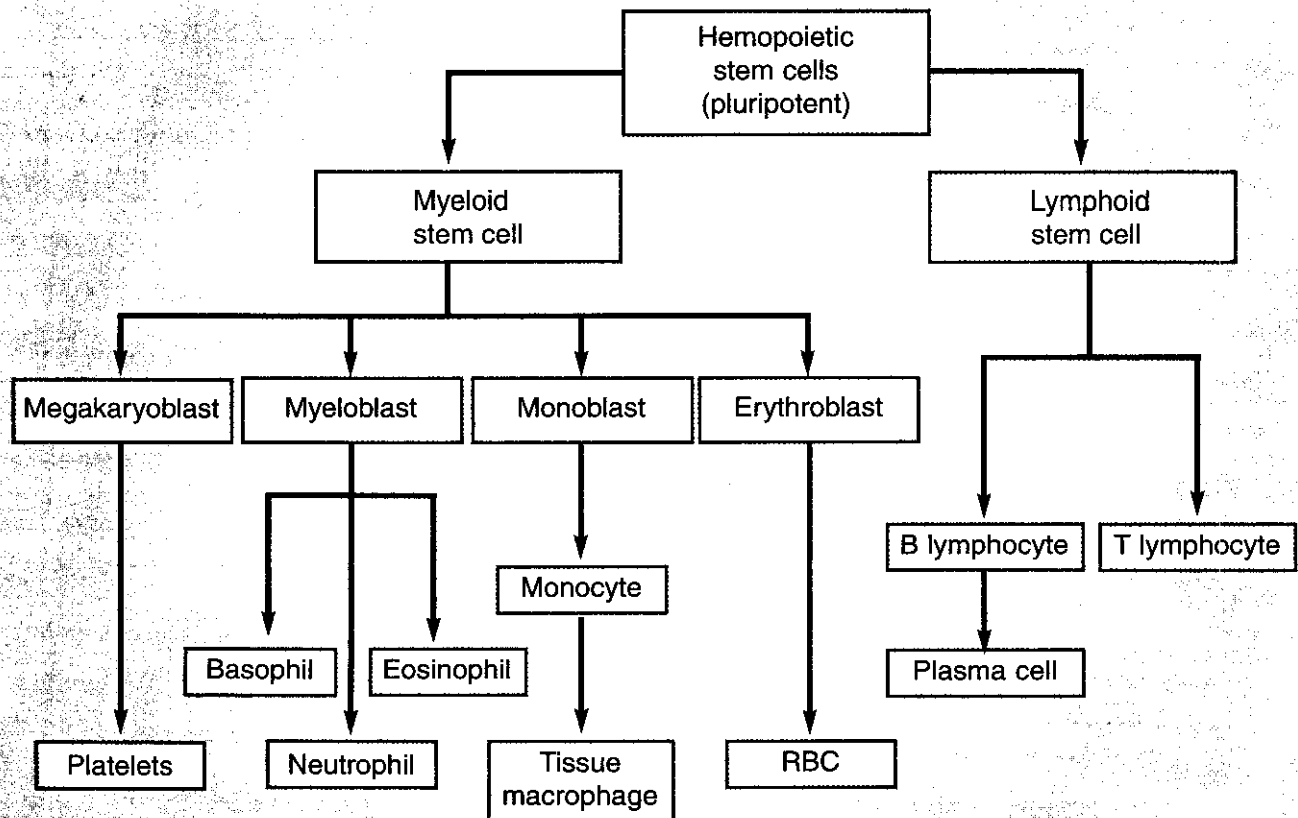


FIGURE 2-6 Origin and maturation of blood cells

Inherited Hematological Diseases

Some hematological diseases, such as *hemophilia*, are inherited. Hemophiliacs have bleeding problems either because they lack one of the coagulation factors required for blood to clot or one of the coagulation factors is defective. In other inherited hematological diseases, patients have abnormal hemoglobin function, such as that caused by the abnormal structure of hemoglobin in *sickle cell anemia*.

Secondary or Acquired Hematological Diseases

Abnormalities in blood cells can also occur because of a condition or disease originating in another organ system. These are called secondary or acquired conditions. For example, abnormal-appearing red blood cells can be present in patients with severe hypertension or renal failure because the cells become damaged as they circulate through small blood vessels. Diabetics may have "lazy leukocytes," which results in slow healing of wounds or infections because some white blood cells function improperly. In infectious mononucleosis, a viral disease, lymphocytes develop an "atypical" appearance that can be observed when a stained blood smear is examined microscopically.

Blood cells are also affected by treatments or medications. High doses of aspirin inhibit platelet function, a temporary condition that corrects itself after aspirin is discontinued. Chemotherapy treatments designed to stop the growth of cancer cells can also inhibit blood cell production. Patients receiving chemotherapy must have regular blood cell counts to be sure their blood cell concentrations do not fall to dangerous levels.

THE HEMATOLOGY LABORATORY

Methods of Analysis in the Hematology Laboratory

Routine hematology tests can be performed manually or using one of the many types of hematology analyzers available. Some are designed for small facilities such as physician office laboratories (POLs) and can perform only a few different tests. Others suitable for large laboratories are designed to perform several analyses on hundreds of samples daily. Lesson 2-13, Principles of Automated Hematology, describes the principles behind the design of hematology analyzers.

All laboratories that use hematology analyzers must also have backup systems for performing analyses in the event of instrument malfunction. Therefore, it is always advisable that personnel be trained in manual techniques for the most frequently requested tests.

Safety Precautions




Standard Precautions must be observed at all times in the hematology laboratory, as in any other laboratory section. Workers must use

proper work practice controls to avoid body fluid spills, splatters, aerosol formation, or other potential exposure to blood and body fluids. Lesson 1-6 contains detailed laboratory biosafety information.

In many facilities, the hematology department is responsible for blood collection as well as hematology testing. Phlebotomists must wear gloves and other appropriate protective clothing such as fluid-resistant laboratory coats, goggles, and masks. Safety shields or face protection can be used in the blood-collecting area, as well as the testing area, to protect against exposure from splashes. Used venipuncture needles must not be recapped but must be discarded into puncture-proof biohazard containers for sharps. The use of safety needles that automatically resheath or enclose the used needle is required and eliminates most needle-stick hazards (Lesson 1-6).

Hematology laboratory workers often have greater potential for exposure to bloodborne pathogens than workers in some other laboratory departments. A blood sample tube used to perform a complete blood count (CBC), blood smears, and sedimentation rate, three separate tests, may have to be opened three times, creating three potential exposure events. Instruments capable of sampling specimens by piercing through the tube stoppers can minimize this type of exposure potential.

Quality Assessment

 In clinical chemistry departments, certified standards for substances such as glucose or sodium are easily obtained. In hematology, however, stable standards are, for the most part, not available. A standard should be as close as possible in composition to the substance being measured and ideally should be stable over a long period. This is not possible with blood cells, since they are living tissues.

The hemoglobin standard is the only true hematology standard. Cell counts and differential counts are standardized using control solutions. Controls for cell counts and automated differentials are made with stabilized cells and have a limited shelf-life of 120 days in the unopened vial but sometimes as short as 5 days once the vial is opened. Controls made with suspensions of latex particles can have a shelf-life of 24 months in the unopened vial but only 30 days once the vial is opened. Hematology controls are available for cell counts, automated differentials, and flow cytometry. Because of the unavailability of true standards, many hematology procedures and instruments require more complex calibration and standardization.

Specimens for Hematology Testing

Both capillary and venous blood are used for routine hematology procedures. Capillary blood obtained by skin puncture is good for procedures such as blood smears because no chemicals are added to the sample to alter cell appearance (Lesson 1-12). However, since only a small sample volume is obtained by capillary puncture, tests usually cannot be repeated unless another sample is obtained.

When a larger sample is required, blood is obtained from a vein by venipuncture (Lesson 1-13). Venous blood samples

CURRENT TOPIC

WHAT ARE STEM CELLS?

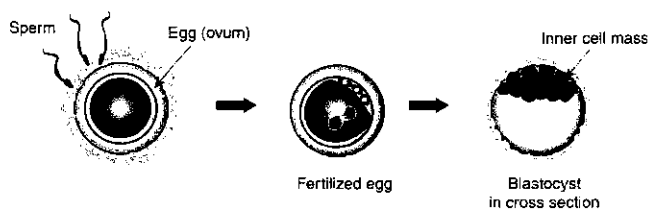
Stem cells are often in the news, in relation either to controversy over funding for research or to scientific or medical news about stem cells as a potential cure for a disease or a genetic defect. But what are stem cells, what is their origin, where are they found, and why are they important?

What are stem cells? Stem cells are undifferentiated cells that have the ability to renew themselves by cell division and also have potential to develop into many different types of specialized cells that make up the tissues and organs of the body. The ability of stem cells to replicate themselves means that they can sometimes be grown in the laboratory and studied. Stem cells cannot give rise to a complete organism.

What is the origin of stem cells? Where are they found? Researchers work with two types of stem cells: adult stem cells and embryonic stem cells. These have different sources and different characteristics.

Adult stem cells—Although termed *adult*, adult stem cells are found in low numbers in various tissues and organs of animals and humans of all ages. Typically they can give rise to specialized cells of the organ in which they reside. They are also called *multipotent* cells, meaning they have the potential (potent) to develop into several (multi) cell types. Within our bodies, adult stem cells are our repair systems, replenishing our damaged cells.

The *hematopoietic stem cells* found in the bone marrow are examples of adult stem cells. They can develop into several types of blood cells (such as red cells, white cells, or megakaryocytes) but normally cannot become cells of other tissues, such as kidney or muscle. Bone marrow transplants are successful because the adult stem cells within the transplanted marrow colonize and reproduce to form new blood cells in the transplant recipient. Hematopoietic stem cells can also be harvested from umbilical cord blood and used for transplant. An advantage of cord blood transplant over bone marrow transplant is that cord blood cells are less likely to be rejected by the recipient because cord blood stem cells have not yet developed markers that could stimulate rejection by the recipient.



Embryonic stem cells—When a sperm fertilizes an egg, a single cell is formed, the fertilized egg (see diagram). This single cell has the potential to form an entire organism; that is, the cell is *totipotent*. A few hours after fertilization, this cell divides into several identical cells, any of which still has the potential to develop into an organism. After about 4 days and several cell divisions, the cells become more specialized (*pluripotent*). A *blastocyst* is formed, with an outer layer of cells (the trophoblast) and an *inner cell mass* of about 30 to 150 cells (see diagram). The cells in the inner mass have the potential to produce a complete fetus if implantation and development proceed normally. Once removed from the blastocyst, they no longer have the potential to form an individual even though they remain *pluripotent*, meaning they have the potential to give rise to all the tissues of the organism. Embryonic stem cells are derived from this inner cell mass of the blastocyst.

In vitro fertilization clinics store fertilized eggs at the blastocyst stage, and blastocysts that are not to be used can be donated to research. Embryonic stem cells obtained from the inner cell mass can be cultured (grown) in the research laboratory under conditions in which the cells continue to divide but do not differentiate or specialize. Cells that survive several months of laboratory growth and replication, and that remain pluripotent and genetically normal, can be used as *embryonic stem cell lines*.

Why are stem cells important? Stem cell researchers foresee almost unlimited possibilities for using stem cells to treat disease, injuries, and genetic disorders—these are called *cell-based therapies*. With further research to learn how to direct the specialization of stem cells, patients who need organ transplants may be able to be treated instead with stem cells. Stem cells could generate new heart tissue when transplanted into a heart; diabetics could grow new insulin-producing cells by receiving stem cell transplants; and Parkinson's disease could be treated by transplants of stem cells that can be induced to become dopamine neurons. Stem cells could also be used as a renewable source of cells to treat diseases and injuries such as spinal cord injury, stroke, Alzheimer's, burns, and arthritis, as well as a way to test new drugs. Stem cells are fascinating and somewhat miraculous in their innate ability to respond to stimulation and develop into a predictable precursor of certain tissues or cells.

for hematology tests are usually collected in a tube containing an anticoagulant to prevent clotting. The anticoagulant most frequently used in the hematology laboratory is EDTA (ethylenediaminetetraacetic acid). Sodium citrate is commonly used as an anticoagulant for coagulation tests.

The Complete Blood Count

One of the most frequently requested procedures in the hematology laboratory is the CBC, or complete blood count. The CBC is a combination of tests that usually includes:

- Red blood cell count
- White blood cell count
- Hemoglobin
- Hematocrit
- Red blood cell indices (MCV, MCH, MCHC)
- Differential count
- Platelet count or platelet estimate
- Evaluation of blood cell morphology

An example of a hematology requisition is shown in Figure 2-7. The methods for performing these tests are explained in the remaining lessons of this unit. After completing this unit, the student should be able to perform several tests included in the CBC.

Coagulation Tests and Special Hematology Tests

Many tests other than those included in the CBC are performed in the hematology laboratory. Some of these, such as the erythrocyte sedimentation rate and reticulocyte count, are included in this unit. Basic coagulation tests, such as the prothrombin time and bleeding time, are explained in Unit 3, Basic Hemostasis. Other hematology tests beyond the scope of this book include special stains for blood and bone marrow cells to classify leukemias; identifying hemoglobin variants, such as the hemoglobin that causes sickle cell anemia; assessing iron status; and testing leukocyte function to help diagnose immune deficiencies.

SUMMARY

Hematology is the study of the formed elements of the blood and the blood-forming tissues. Blood is composed of the cellular elements suspended in plasma, the fluid portion of blood. The cellular elements are commonly called blood cells and include the red blood cells, the white blood cells, and the platelets. The red cells function in respiration, the white cells in immunity, and the platelets in hemostasis.

Hemopoiesis, the formation and development of blood cells, begins in the liver in the early fetus. By the time of birth, the bone marrow has taken over blood cell production. Blood cells, derived from primitive stem cells, continue to be produced throughout an individual's life. Knowledge of the circulatory system, the blood vessels, and the composition of blood is necessary when studying or working in hematology.

HEMATOLOGY									
CBC		HGB & HCT		WBC		PLATELET CT.		TEST NO.	
SA		OP CODES		NORMAL VALUES		42474			
		WBC	M	7.8-13					
		HGB	M	12-16	F	11.5-15.5			
		HCT	M	37-47	F	37-47			
		MCV	M	87-101	F	87-101			
		MCH	M	27-32	F	27-32			
		MCHC	M	32-36	F	32-36			
		RBC	M	4.5-5.5	F	4.5-5.5			
		PLT	M	130-400	F	130-400			
		MPV	M	8.9-11.5	F	8.9-11.5			
		LYMPH %	M	20-40	F	20-40			
		LYMPH $\times 10^3$	M	2.0-5.1	F	2.0-5.1			
SEGS		NORMAL RBC							
BANDS		MORPH	1	2	3	4			
LYMPHS		POLYCHROM							
MONOS		HYPOCHROM							
EOS		POIK							
BASOS		TARGET							
ATYP LYMPHS		SPHERO							
MET		ANISO							
MYELO		MICRO							
PRO		MACRO							
BLAST		SICKLE CELLS							
		SABD STP							
		TOXIC GRAN							
NRBC/100 WBC		1. SLIGHT 2. MODERATE 3. MOD TO MARKED 4. MARKED							
WBC CT CORRECTED FOR PLATELETS									
PLATELETS CKY									
REMARKS (For Lab Use Only)									
COLLECTED BY	REPORTED BY	CALLED BY							
TECHNURSE	TECH	BY							
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TIME	TIME	TIME							
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FIGURE 2-7 Hematology requisition form

Tests performed in the hematology laboratory can be qualitative, such as observation and evaluation of blood cell morphology, or quantitative, such as the red blood cell and white blood cell counts or determination of the hematocrit. The majority of testing is performed using instrumentation. However, manual methods are sometimes required when instrumentation is not available or in cases in which a low white blood cell count or platelet count is expected.

Safety and quality assessment programs are important in hematology. Standard Precautions must always be observed. Hematology personnel can have increased chance of exposure to potentially infectious specimens compared to personnel in some other areas of the laboratory. A comprehensive quality assessment program is essential to ensure that test results are accurate and useful. Hematology tests can give much information about the general well-being of a patient. In addition, hematology test results can be

used to monitor the effects of chemotherapy or radiation treatments and to provide information critical to the diagnosis of conditions such as anemias, leukemias, and coagulation disorders.

REVIEW QUESTIONS

1. Where are blood cells produced? What is the most primitive blood cell called?
2. What are the three groups of formed elements in the blood? What are the functions of each group?
3. Name the five types of leukocytes found in the blood. Which are the granulocytes?
4. Name five components of plasma.
5. What two types of blood specimens are used for most hematological tests?
6. What anticoagulant is used for most hematological tests? For most coagulation tests?
7. Name the three major types of blood vessels and explain the differences among them.
8. Name three ways workers can lessen the chance of exposure to blood and body fluids in the hematology laboratory.
9. Which blood component is responsible for oxygen exchange?
10. Name an inherited hematological disease. What is meant by a secondary or acquired hematological condition?
11. What is a CBC?
12. How does hematology quality assessment differ from quality assessment in clinical chemistry?
13. Define anemia, anticoagulant, artery, capillary, cardiopulmonary circulation, CBC, deoxyhemoglobin, EDTA, erythrocyte, granulocyte, hematopoietic stem cell, hematology, hemoglobin, hemopoiesis, hematology, hemopoietic stem cell, hemostasis, leukemia, leukocyte, megakaryocyte, oxyhemoglobin, plasma, platelet, red blood cell, stem cell, systemic circulation, thrombocyte, vein, and white blood cell.

STUDENT ACTIVITIES

1. Complete the written examination for this lesson.
2. Visit a hematology laboratory in the community. Find out what tests are performed there.

WEB ACTIVITY

Research a hematological disease using the Internet. Report on the cause of the disease, the laboratory tests that can be used for diagnosis, and the appropriate treatment. Possible sources are Web sites of NIH, medical schools, or universities.