Chapter Ten

Blood and Immunity

Chapter Contents

Objectives

After study of this chapter you should be able to:

1. Describe the composition of the blood plasma.
2. Describe and give the functions of the three types of blood cells.
3. Label pictures of the blood cells.
4. Explain the basis of blood types.
5. Define immunity and list the possible sources of immunity.
6. Identify and use roots and suffixes pertaining to the blood and immunity.
7. Identify and use roots pertaining to blood chemistry.
8. List and describe the major disorders of the blood.
9. List and describe the major disorders of the immune system.
10. Describe the major tests used to study blood.
11. Interpret abbreviations used in blood studies.
12. Analyse several case studies involving the blood.

Pretest

1. The scientific name for red blood cells is _____.
2. The scientific name for white blood cells is _____.
3. Platelets, or thrombocytes, are involved in _____.
4. The white blood cells active in adaptive immunity are the _____.
5. Substances produced by immune cells that counteract microorganisms and other foreign materials are called _____.
6. A deficiency of hemoglobin results in the disorder called _____.
7. A neoplasm involving overgrowth of white blood cells is called _____.

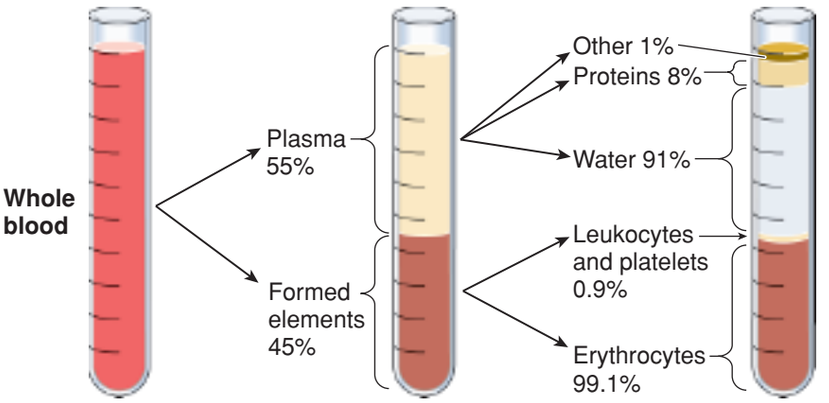


Figure 10-1 Composition of whole blood. Percentages show the relative proportions of the different components of plasma and formed elements.

Blood

Blood circulates through the vessels, bringing oxygen and nourishment to all cells and carrying away carbon dioxide and other waste products. The blood also distributes body heat and carries special substances, such as antibodies and hormones. The total adult blood volume is about 5 liters (5.2 quarts). Whole blood can be divided into two main components: the liquid portion, or **plasma** (55%), and **formed elements,** or blood cells (45%) (Fig. 10-1).

Blood Plasma

Plasma is about 90% water. The remaining 10% contains nutrients, **electrolytes** (dissolved salts), gases, **albumin** (a protein), clotting factors, antibodies, wastes, enzymes, and hormones. A multitude of these substances are tested for in blood chemistry tests. The pH (relative acidity) of the plasma remains steady at about 7.4.

Blood Cells

The blood cells (Fig. 10-2) are **erythrocytes,** or red blood cells (RBCs); **leukocytes,** or white blood cells (WBCs); and **platelets,** also called **thrombocytes.** All blood cells are produced in red bone marrow. Some white blood cells multiply in lymphoid tissue as well. Reference Box 10-1 summarises the different types of blood cells; Box 10-2 discusses time-saving acronyms, such as RBC and WBC.

Erythrocytes

The major function of erythrocytes is to carry oxygen to cells. This oxygen is bound to an iron-containing pigment in the cells called **hemoglobin.** Erythrocytes are small, disk-shaped cells with no nucleus (Fig 10-3). Their concentration of about 5 million per µL (microlitre; mcL) of blood makes them by far the most numerous of the blood cells. The

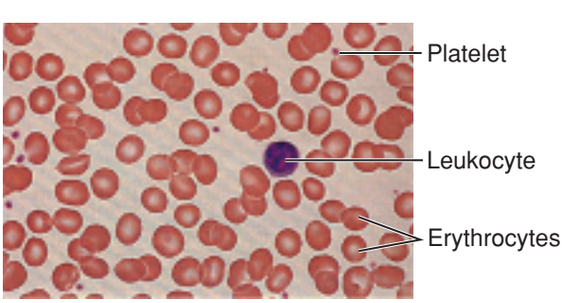


Figure 10-2 Blood cells. When viewed under a microscope, all three types of formed elements are visible.

Box 10•1 For Your Reference — *Blood Cells*

Cells	Number per μL of Blood	Description	Function
Erythrocyte (red blood cell)	5 million	Tiny (7 μm diameter), biconcave disk without nucleus (anuclear)	Carries oxygen bound to hemoglobin; also carries some carbon dioxide and buffers blood
Leukocyte (white blood cell)	5,000 to 10,000	Larger than red cell with prominent nucleus that may be segmented (granulocyte) or unsegmented (agranulocyte); varies in staining properties	Protects against pathogens. Destroys foreign matter and debris. Some are active in the immune system. Located in blood, tissues, and lymphatic system.
Platelet	150,000 to 450,000	Fragment of large cell (megakaryocyte)	Hemostasis. Forms a platelet plug and starts blood clotting (coagulation).

hemoglobin that they carry averages 15 g per dL (100 mL) of blood. A red blood cell gradually wears out and dies in about 120 days, so these cells must be constantly replaced. Production of red cells in the bone marrow is regulated by the hormone **erythropoietin** (EPO), which is made in the kidneys.

Leukocytes

White blood cells all show prominent nuclei when stained (Fig. 10-4). They total about 5000 to 10,000 per μL, but their number may increase during infection. There are five types of leukocytes, which are identified by the size and appearance of the nucleus and by their staining properties:

- **Granulocytes,** or granular leukocytes, have visible granules in the cytoplasm when stained. The nucleus of a granulocyte is segmented. There are three types of granulocytes, named for the kind of stain (dye) they take up:

Box 10•2 Focus on Words — *Acronyms*

Acronyms are abbreviations that use the first letters of the words in a name or phrase. They have become very popular because they save time and space in writing as the number and complexity of technical terms increases. Some examples that apply to studies of the blood are CBC (complete blood count) and RBC and WBC for red and white blood cells. Some other common acronyms are CNS (central nervous system), ECG (electrocardiograph), NIH (National Institutes of Health), and STI (sexually transmitted infection).

If the acronym has vowels and lends itself to pronunciation, it may be used as a word in itself, such as AIDS (acquired immunodeficiency syndrome); ELISA (enzyme-linked immunosorbent assay); JAMA (*Journal of the American Medical Association*); NSAID (nonsteroidal antiinflammatory agent), pronounced "en-sayd"; and CABG (coronary artery bypass graft), which inevitably becomes "cabbage." Few people even know that LASER is an acronym that means "light amplification by stimulated emission of radiation."

An acronym usually is introduced the first time a phrase appears in an article and is then used without explanation. If you have spent time searching back through an article in frustration for the meaning of an acronym, you probably wish, as does this author, that all the acronyms used and their meanings would be listed at the beginning of each article.

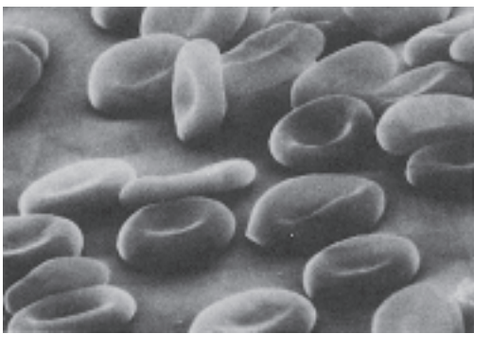


Figure 10-3 Erythrocytes (red blood cells). The cells are seen under a scanning electron microscope, which gives a three-dimensional view.

- **Neutrophils** stain with either acidic or basic dyes.
- **Eosinophils** stain with acidic dyes.
- **Basophils** stain with basic dyes.

- **Agranulocytes** do not show visible granules when stained. The nucleus of an agranulocyte is large and either round or curved. There are two types of agranulocytes:
  - **Lymphocytes,** which are the smaller agranulocytes.
  - **Monocytes,** which are the largest of all the white blood cells.

White blood cells protect against foreign substances. Some engulf foreign material by the process of **phagocytosis**; others function as part of the immune system. In diagnosis it is important to know not only the total number of leukocytes but also the relative number of each type because these numbers can change in different disease conditions. Reference Box 10-3 gives the relative percentage and functions of the different types of white cells.

The most numerous white blood cells, neutrophils, are called *polymorphs* because of their various-shaped nuclei. They are also referred to as *segs, polys,* or *PMNs* (*poly*morpho*nuclear* leukocytes). A **band cell,** also called a *stab cell*, is an immature neutrophil with a solid curved nucleus (Fig. 10-5). Large numbers of band cells in the blood indicate an active infection.

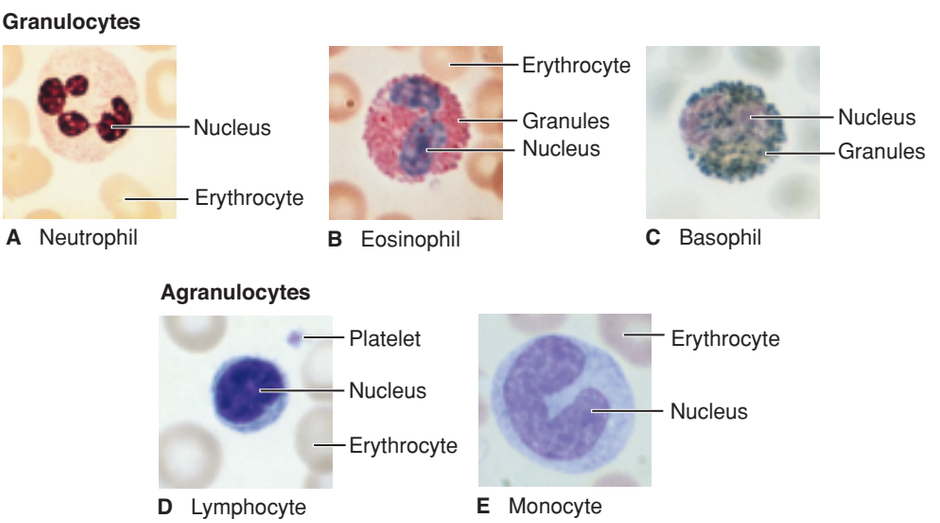


Figure 10-4 Leukocytes (white blood cells). The three types of granulocytes (*A–C*) have visible granules in the cytoplasm when stained. The two types of agranulocytes (*D, E*) do not show granules when stained.

Box 10•3 For Your Reference *White Blood Cells (Leukocytes)*

Type of Cell	Relative Percentage (Adult)	Function
GRANULOCYTES		
neutrophils *NŪ-trō-fils*	54%–62%	phagocytosis
eosinophils *ē-ō-SIN-ō-fils*	1%–3%	allergic reactions; defense against parasites
basophils *BĀ-sō-fils*	less than 1%	allergic reactions
AGRANULOCYTES		
lymphocytes *LIMF-ō-sītz*	25%–38%	immunity (T cells and B cells)
monocytes *MON-ō-sītz*	3%–7%	phagocytosis

Platelets

The blood platelets (thrombocytes) are not complete cells, but fragments of large cells named **megakaryocytes,** which form in bone marrow (Fig. 10-6). They number from 200,000 to 400,000 per µL of blood. Platelets are important in **hemostasis,** the prevention of blood loss, one part of which is the process of blood clotting, or **coagulation.**

When a vessel is injured, platelets stick together to form a plug at the site. Substances released from the platelets and from damaged tissue then interact with clotting factors in the plasma to produce a wound-sealing clot. Clotting factors are inactive in the blood until an injury occurs. To protect against unwanted clot formation, 12 factors must interact before blood coagulates. The final reaction is the conversion of **fibrinogen** to threads of **fibrin** that trap blood cells and plasma to produce the clot (Fig. 10-7). What remains of the plasma after blood coagulates is **serum.**

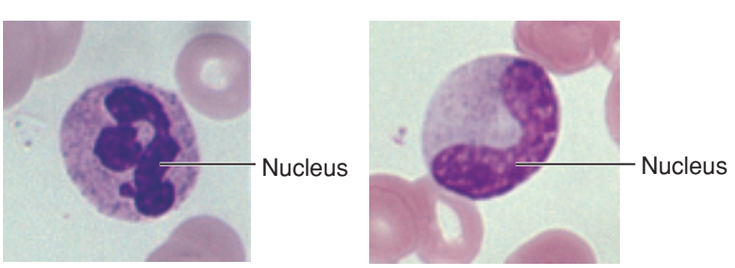


Figure 10-5 Band cell. (*A*) A mature neutrophil. (*B*) A band cell, or stab cell, is an immature neutrophil with a thick curved nucleus.

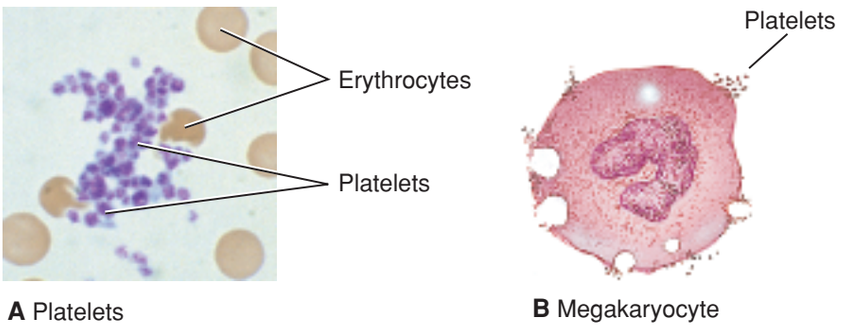


Figure 10-6 Platelets (thrombocytes). (*A*) Platelets seen in a blood smear under the microscope. (*B*) A megakaryocyte releases platelets.

Blood Types

Genetically inherited proteins on the surface of red blood cells determine blood type. More than 20 groups of these proteins have now been identified, but the most familiar are the ABO and Rh blood groups. The ABO system includes types A, B, AB, and O. The Rh types are Rh-positive (Rh^+) and Rh-negative (Rh^-).

In giving blood transfusions, it is important to use blood that is the same type as the recipient's blood or a type to which the recipient will not have an immune reaction, as described below. Compatible blood types are determined by **cross-matching** (Fig. 10-8). When a blood sample is mixed separately with different antisera, its red cells will agglutinate (clump) with the antiserum that corresponds to its blood type.

Whole blood may be used to replace a large volume of blood lost, but in most cases requiring blood transfusion, a blood fraction such as packed red cells, platelets, plasma, or specific clotting factors is administered.

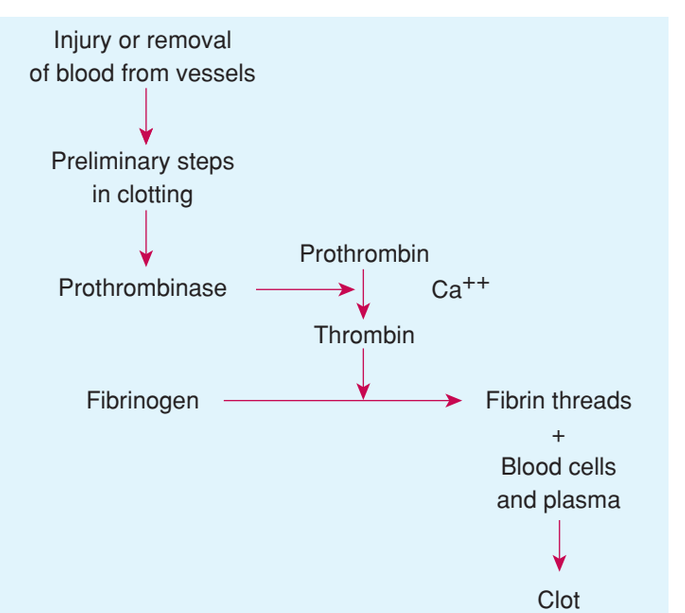


Figure 10-7 Main steps in the formation of a blood clot.

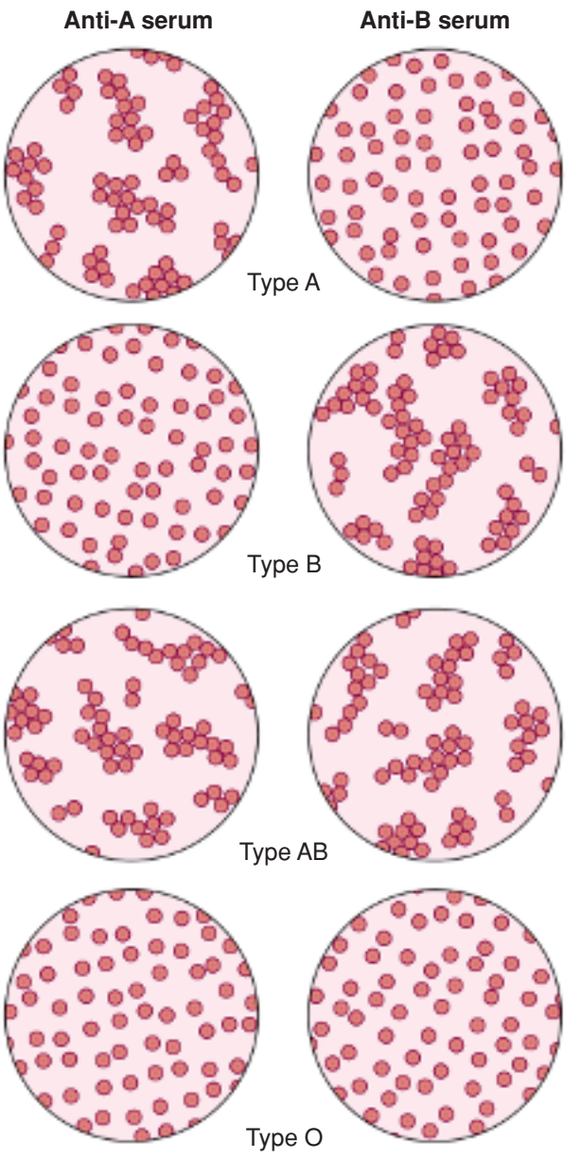


Figure 10-8 Blood typing. Labels at the top of each column denote the kind of antiserum added to the blood samples. Anti-A serum agglutinates red cells in type A blood, but anti-B serum does not. Anti-B serum agglutinates red cells in type B blood, but anti-A serum does not. Both sera agglutinate type AB blood cells, and neither serum agglutinates type O blood.

Immunity

Immunity is protection against disease. It includes defenses against harmful microorganisms, their products, or any other foreign substance. These defenses may be inborn or acquired during life (Fig. 10-9).

Innate Immunity

Innate defense mechanisms are inborn; they are based on the genetic makeup of the individual. Most of these defenses are physical mechanisms and are nonspecific (i.e., they protect against any intruder), and include:

- Unbroken skin, which acts as a barrier.
- Cilia, tiny cell projections that sweep impurities out of the body, as in the respiratory tract.
- Mucus that traps foreign material.

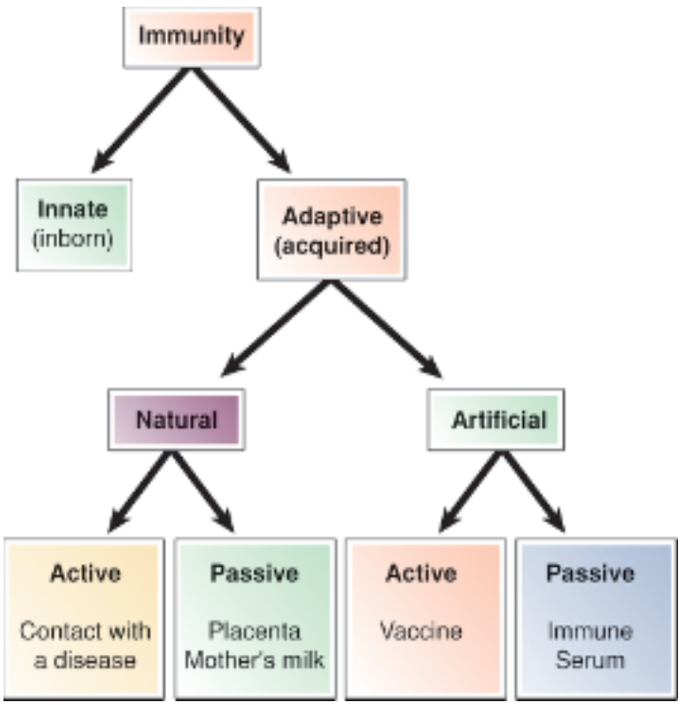


Figure 10-9 **Types of immunity.**

- Bactericidal body secretions, as found in tears, the skin, the digestive tract, and the reproductive tract.
- Reflexes, such as coughing and sneezing, which expel impurities.
- Lymphoid tissue, which filters impurities from blood and lymph, as described in Chapter 9.
- Phagocytes—cells that attack, ingest, and destroy foreign organisms.

Adaptive Immunity

Adaptive immunity is acquired during life and is specific, which means that it is directed toward a particular disease organism or other foreign substance. Thus, protection against measles, for example, will not protect against chickenpox or any other disease.

The specific immune response involves complex interactions between components of the lymphatic system and the blood. Any foreign particle, but mainly proteins, may act as an **antigen,** a substance that provokes an immune response. This response comes from two types of lymphocytes that circulate in the blood and lymphatic system:

- **T cells** (T lymphocytes), mature in the thymus gland. They are capable of attacking a foreign cell directly, producing *cell-mediated immunity.* **Macrophages,** descendants of monocytes, are important in the function of T cells. Macrophages take in and process foreign antigens. A T cell is activated when it contacts an antigen on the surface of a macrophage in combination with some of the body's own proteins.
- **B cells** (B lymphocytes) mature in bone marrow. When they meet a foreign antigen, they multiply rapidly and mature into **plasma cells.** These cells produce **antibodies**, also called **immunoglobulins** (Ig), that inactivate antigens (Fig. 10-10). Antibodies remain in the blood, often providing long-term immunity to the specific organism against which they were formed. Antibody-based immunity is referred to as *humoral immunity.*

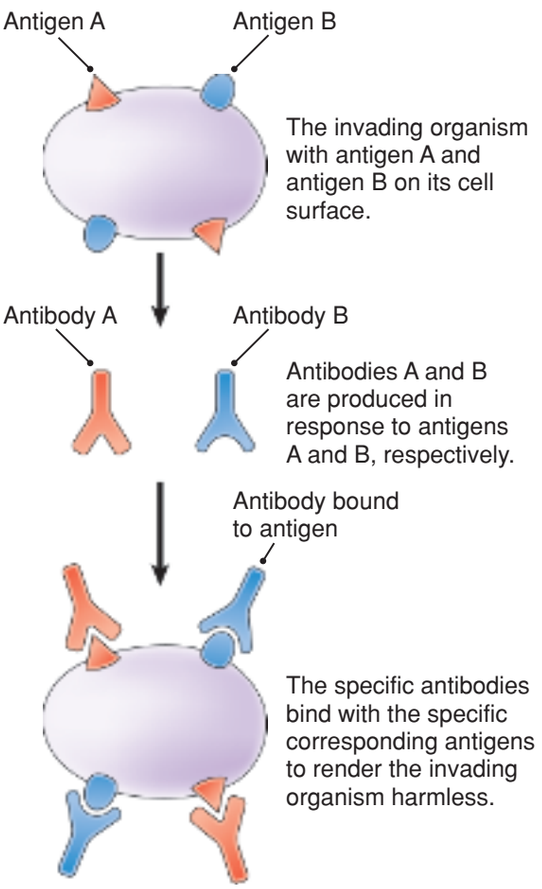


Figure 10-10 The antigen-antibody reaction. Antibodies produced by immune cells bind with specific antigens to aid in their inactivation and elimination.

Types of Adaptive Immunity

Adaptive immunity may be acquired either naturally or artificially (see Fig. 10-9). In addition, each avenue for acquiring immunity may be either active or passive. In active immunity, a person makes his or her own antibodies in response to contact with an antigen. In passive immunity, an antibody, known as an immune serum, is transferred from an outside source. Immune sera may come from other people or from immunised animals. The portion of the blood plasma that contains antibodies is the **gamma globulin** fraction. The types of adaptive immunity are:

- Natural adaptive immunity
  - Active—from contact with a disease organism or other foreign antigen
  - Passive—by transfer of antibodies from a mother to her fetus through the placenta or through the mother's milk

- Artificial adaptive immunity
  - Active—by administration of a vaccine, which may be a killed or weakened organism, part of an organism, or an altered toxin (toxoid)
  - Passive—by administration of an immune serum obtained from other people or animals

Immunology has long been a very active area of research. The above description is only the barest outline of the events that are known to occur in the immune response, and there is much still to be discovered. Some of the areas of research include autoimmune diseases, in which an individual produces antibodies to his or her own body tissues; hereditary and acquired immunodeficiency diseases; the relationship between cancer and immunity; and the development of techniques for avoiding rejection of transplanted tissue.

TERMINOLOGY Key Terms

NORMAL STRUCTURE AND FUNCTION

agranulocytes *Ā-gran-ū-lō-sītz*	White blood cells that do not have visible granules in their cytoplasm. Agranulocytes include lymphocytes and monocytes (see Fig. 10-4).
albumin *al-BŪ-min*	A simple protein found in blood plasma
antibody *AN-tē-bod-ē*	A protein produced in response to, and interacting specifically with, an antigen
antigen *AN-ti-jen*	A substance that induces the formation of an antibody
B cell	A lymphocyte that matures in lymphoid tissue and is active in producing antibodies; B lymphocyte (*LIMF-ō-sīt*)
band cell	An immature neutrophil with a nucleus in the shape of a band; also called a stab cell. Band-cell counts are used to trace infections and other diseases (see Fig. 10-5).
basophil *BĀ-sō-fil*	A granular leukocyte that stains with basic dyes; active in allergic reactions
blood	The fluid that circulates in the cardiovascular system (root: *hem/o, hemat/o*)
coagulation *kō-ag-ū-LĀ-shun*	Blood clotting
cross-matching	Testing the compatibility of donor and recipient blood in preparation for a transfusion. Donor red cells are mixed with recipient serum, and red cells of the recipient are mixed with donor serum to look for an immunologic reaction. Similar tests are done on tissues before transplantation.
electrolyte *ē-LEK-trō-līt*	A substance that separates into charged particles (ions) in solution; a salt. Term also applied to ions in body fluids.
eosinophil *ē-ō-SIN-ō-fil*	A granular leukocyte that stains with acidic dyes; active in allergic reactions and defense against parasites
erythrocyte *e-RITH-rō-sīt*	A red blood cell (root: *erythr/o, erythrocyt/o*) (see Figs. 10-2 and 10-3)
erythropoietin (EPO) *e-rith-rō-POY-e-tin*	A hormone produced in the kidneys that stimulates red-blood-cell production in the bone marrow. This hormone is now made by genetic engineering for clinical use.
fibrin *Fī-brin*	The protein that forms a clot in the process of blood coagulation
fibrinogen *fi-BRIN-ō-jen*	The inactive precursor of fibrin
formed elements	The cellular components of blood
gamma globulin *GLOB-ū-lin*	The fraction of the blood plasma that contains antibodies; given for passive transfer of immunity
granulocytes *GRAN-ū-lō-sītz*	White blood cells that have visible granules in their cytoplasm. Granulocytes include neutrophils, basophils, and eosinophils (see Fig 10-4).

TERMINOLOGY Key Terms

Continued

hemoglobin (Hb, Hgb) *HĒ-mō-glō-bin*	The iron-containing pigment in red blood cells that transports oxygen
hemostasis *hē-mō-STĀ-sis*	The stoppage of bleeding
immunity	The state of being protected against a specific disease (root: *immun/o*)
immunoglobulin (Ig) *im-ū-nō-GLOB-ū-lin*	An antibody. Immunoglobulins fall into five classes, each abbreviated with a capital letter: IgG, IgM, IgA, IgD, IgE.
leukocyte *LŪ-kō-sīt*	A white blood cell (root: *leuk/o, leukocyt/o*)
lymphocyte *LIMF-ō-sīt*	An agranular leukocyte active in immunity (T cells and B cells); found in both the blood and in lymphoid tissue (root: *lymph/o, lymphocyt/o*)
megakaryocyte *meg-a-KAR-ē-ō-sīt*	A large bone marrow cell that fragments to release platelets
macrophage *MAK-rō-faj*	A phagocytic cell derived from a monocyte; usually located within the tissues. Macrophages process antigens for T cells.
monocyte *MON-ō-sīt*	An agranular phagocytic leukocyte
neutrophil *NŪ-trō-fil*	A granular leukocyte that stains with acidic or basic dyes. The most numerous of the white blood cells. A type of phagocyte.
phagocytosis *fag-ō-sī-TŌ-sis*	The engulfing of foreign material by white blood cells
plasma *PLAZ-ma*	The liquid portion of the blood
plasma cell	A mature form of a B cell that produces antibodies
platelet *PLĀT-let*	A formed element of the blood that is active in hemostasis; a thrombocyte (root: *thrombocyt/o*)
serum *SER-um*	The fraction of the plasma that remains after blood coagulation; it is the equivalent of plasma without its clotting factors (plural: sera, serums).
T cell	A lymphocyte that matures in the thymus gland and attacks foreign cells directly; T lymphocyte
thrombocyte *THROM-bō-sīt*	A blood platelet (root: *thrombocyt/o*)

Go to the pronunciation glossary in Chapter 10 on the CD-ROM to hear these words pronounced.

Word Parts Pertaining to Blood and Immunity

Table 10•1 Suffixes for Blood

SUFFIX	MEANING	EXAMPLE	DEFINITION OF EXAMPLE
-emia,* -hemia	condition of blood	erythremia *er-i-THRĒ-mē-a*	increase in red cells in the blood
-penia	decrease in, deficiency of	cytopenia *sī-tō-PĒ-nē-a*	deficiency of cells in the blood
-poiesis	formation, production	hemopoiesis *hē-mō-poy-Ē-sis*	production of blood cells

**A shortened form of the root hem plus the suffix -ia.*

Exercise 10-1

Define the following terms:

1. hypoproteinemia (*hī-pō-prō-tēn-Ē-mē-a*) decreased protein in the blood
2. hyperalbuminemia (*hī-per-al-bū-mi-NĒ-mē-a*) _____
3. erythrocytopenia (*e-rith-rō-sī-tō-PĒ-nē-a*) _____
4. toxemia (*tok-SĒ-mē-a*) _____
5. bacteremia (*bak-ter-Ē-mē-a*) _____
6. erythropoiesis (*e-rith-rō-poy-Ē-sis*) _____

Word building. Use the suffix -emia to write words for the following definitions:

7. Presence of pus in the blood _____
8. Presence of viruses in the blood _____
9. Presence of excess white cells (*leuk/o-*) in the blood _____

Many of the words relating to blood cells can be formed either with or without including the root *cyt/o,* as in erythropenia or erythrocytopenia, leukopoiesis or leukocytopoiesis. The remaining types of blood cells are designated by easily recognized roots such as *agranulocyt/o, monocyt/o, granul/o,* and so on.

Table 10•2 Roots for Blood and Immunity

ROOT	MEANING	EXAMPLE	DEFINITION OF EXAMPLE
myel/o	bone marrow	myelogenous *mī-el-OJ-e-nus*	originating in bone marrow
hem/o, hemat/o	blood	hematology *hē-ma-TOL-ō-jē*	study of blood
erythr/o, erythrocyt/o	red blood cell	erythropoiesis *e-rith-rō-poy-Ē-sis*	formation of blood cells
leuk/o, leukocyt/o	white blood cell	leukoblast *LŪ-kō-blast*	immature white blood cell

Table 10•2 Continued

lymph/o, lymphocyt/o	lymphocyte	lymphocytic *limf-ō-SIT-ik*	pertaining to lymphocytes
thromb/o	blood clot	thrombosis *throm-BŌ-sis*	formation of a blood clot
thrombocyt/o	platelet, thrombocyte	thrombocytopenia *throm-bō-sī-tō-PĒ-nē-a*	deficiency of platelets in the blood
immun/o	immunity, immune system	immunisation *im-ū-nī-SĀ-shun*	production of immunity

Exercise 10-2

Identify and define the root in the following words:

	Root	*Meaning of Root*
1. panmyeloid (*pan-MĪ-e-loyd*)	myel/o	bone marrow
2. prothrombin (*prō-THROM-bin*)		
3. preimmunisation (*prē-im-ū-nī-SĀ-shun*)		
4. ischemia (*is-KĒ-mē-a*)		

Fill in the blanks:

5. Hemorrhage is a profuse flow (-rhage) of _____.
6. Erythroclasis (*er-i-THROK-la-sis*) is the breaking (-clasis) of _____.
7. The term *thrombocythemia* (*throm-bō-sī-THĒ-mē-a*) refers to an increase in the number of _____ in the blood.
8. Leukopoiesis (*lū-kō-poy-Ē-sis*) refers to the production of _____.
9. An immunocyte (*im-ū-nō-SĪT*) is a cell active in _____.
10. A hemocytometer (*hē-mō-sī-TOM-e-ter*) is a device for counting _____.
11. Myelofibrosis (*mī-el-ō-fī-BRO-sis*) is formation of fibrous tissue in _____.
12. Lymphokines (*LIMF-ō-kīnz*) are chemicals active in immunity that are produced by _____.

Word building. Write a word for the following definitions:

13. Immature lymphocyte _____
14. Tumor of bone marrow _____
15. Decrease in red blood cells _____
16. Dissolving (-lysis) of a blood clot _____
17. Formation (-poiesis) of bone marrow _____

The suffix -osis added to a root for a type of cell means an increase in that type of cell in the blood. Use this suffix to write a word that means the same as the following:

18. Increase in granulocytes in the blood granulocytosis
19. Increase in lymphocytes in the blood _____

20. Increase in red blood cells _____
21. Increase in monocytes in the blood _____
22. Increase in platelets in the blood _____

Table 10•3 Roots for Chemistry

ROOT	MEANING	EXAMPLE	DEFINITION OF EXAMPLE
azot/o	nitrogenous compounds	azoturia *ā-zō-TUR-ē-a*	increased nitrogenous compounds in the urine (-uria)
calc/i	calcium (symbol Ca)	calcification *kal-si-fi-KĀ-shun*	deposition of calcium salts
ferr/o, ferr/i	iron (symbol Fe)	ferrous *FER-ous*	pertaining to or containing iron
sider/o	iron	sideroderma *sid-er-ō-DER-ma*	deposition of iron into the skin
kali	potassium (symbol K)	hypokalemia* *hī-pō-ka-LĒ-mē-a*	decrease of potassium in the blood
natri	sodium (symbol Na)	natriuresis *nā-trē-UR-ē-sis*	excretion of sodium in the urine (ur/o)
ox/y	oxygen (symbol O)	hypoxia *hī-POKS-ē-a*	deficiency of oxygen in the tissues

**The i in the root is dropped.*

Exercise 10-3

Fill in the blanks:

1. A sideroblast (*SID-er-ō-blast*) is an immature cell containing _____.
2. The term *hyperkalemia* (*hī-per-ka-LĒ-mē-a*) refers to an excess blood concentration of _____.
3. The bacterial species *Azotobacter* is named for its ability to metabolise _____.
4. Hypoxemia (*hī-poks-Ē-mē-a*) is a blood deficiency of _____.
5. Ferritin (*FER-i-tin*) is a compound that contains _____.
6. A calcareous (*kal-KAR-ē-us*) substance contains _____.

Word building. Use the suffix -emia to form words with the following meanings:

7. Presence of potassium in the blood _____
8. Presence of nitrogenous compounds in the blood _____
9. Presence of sodium in the blood _____
10. Presence of calcium in the blood _____

Clinical Aspects of Blood

Anemia

Anemia is defined as an abnormally low amount of hemoglobin in the blood. Anemia may result from too few red blood cells or from cells that are too small (microcytic) or have too little hemoglobin (hypochromic). Key tests in diagnosing anemia are blood counts, mean corpuscular volume (MCV), and mean corpuscular hemoglobin concentration (MCHC). (Reference Box 10-4 describes these and other blood tests. Box 10-5 has information on careers in hematology.)

Box 10•4 For Your Reference — *Common Blood Tests*

Test	Abbreviation	Description
red-blood-cell count	RBC	number of red blood cells per μL (microlitre) of blood
white-blood-cell count	WBC	number of white blood cells per μL of blood
differential count	Diff	relative percentage of the different types of leukocytes
hematocrit (Fig. 10–11)	Ht, Hct, crit	relative percentage of packed red cells in a given volume of blood
packed cell volume	PCV	hematocrit
hemoglobin	Hb, Hgb	amount of hemoglobin in g/dL (100 mL) of blood
mean corpuscular volume	MCV	volume of an average red cell
mean corpuscular hemoglobin	MCH	average weight of hemoglobin in red cells
mean corpuscular hemoglobin concentration	MCHC	average concentration of hemoglobin in red blood cells
erythrocyte sedimentation rate	ESR	rate of settling of erythrocytes per unit of time; used to detect infection or inflammation
complete blood count	CBC	series of tests including cell counts, hematocrit, hemoglobin, and cell volume measurements

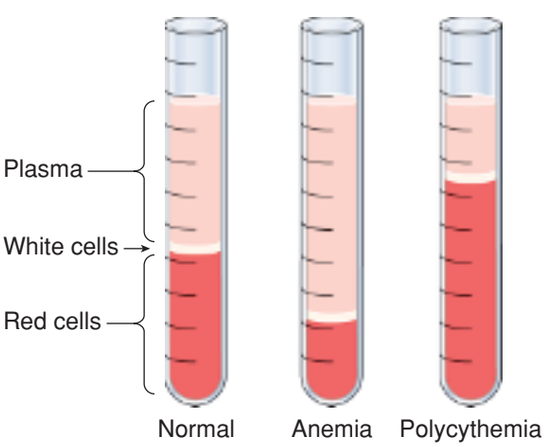


Figure 10-11 Hematocrit. The tube on the left shows a normal hematocrit. The middle tube shows that the percentage of red blood cells is low, indicating anemia. The tube on the right shows an excessively high percentage of red blood cells, as seen in polycythemia.

Box 10•5 Health Professions *Careers in Hematology*

Hematologists are physicians and other scientists who specialise in the study of blood and blood diseases. In medical practice, hematology is often combined with the study and treatment of blood cancers as the specialty hematology–oncology.

A hematology technician is usually a medical laboratory technician who specialises in blood studies. He or she may work in a clinical laboratory, blood banking, industry, or academic research. The job requires a BS or MS in biological science plus training in laboratory procedures, blood pathology, and testing methods. Hematology technicians perform a full range of blood studies for diagnosis of infections, allergies, anemia, leukemia, and other blood diseases. They also run tests to monitor anticoagulant therapy. They must be able to operate and maintain automated equipment used to analyse blood. In some cases, they may also draw blood or administer blood transfusions.

A phlebotomist draws blood for testing, transfusions, or research. The blood is often drawn from a vein (venipuncture), but may also be drawn from arteries and by skin puncture. Phlebotomists must be trained in sterile techniques and safety precautions to prevent the spread of infectious diseases. They must take specimens without harming the patient or interfering with medical care and must transport specimens to the proper laboratory. A phlebotomist is usually a medical laboratory assistant or technician. Phlebotomists work in hospitals, laboratories, private physicians' offices, clinics, and blood banks.

The general symptoms of anemia include fatigue, shortness of breath, heart palpitations, pallor, and irritability. There are many different types of anemia, some of which are caused by faulty production of red cells and others by loss or destruction of red cells.

Anemia Due to Impaired Production of Red Cells

- **Aplastic anemia** results from bone marrow destruction and affects all blood cells (pancytopenia). It may be caused by drugs, toxins, viruses, radiation, or bone marrow cancer. Aplastic anemia has a high mortality rate but has been treated successfully with bone marrow transplantation.
- **Nutritional anemia** may result from a deficiency of vitamin B_{12} or of folic acid, B vitamins needed for RBC development. Most commonly, it is caused by a deficiency of iron, needed to make hemoglobin (Fig. 10-12). Folic acid deficiency commonly appears in those with poor diet, in pregnant and lactating women, and in those who abuse alcohol. Iron-deficiency anemia results from poor diet, poor absorption of iron, or blood loss. Both folic acid deficiency and iron deficiency respond to dietary supplementation.

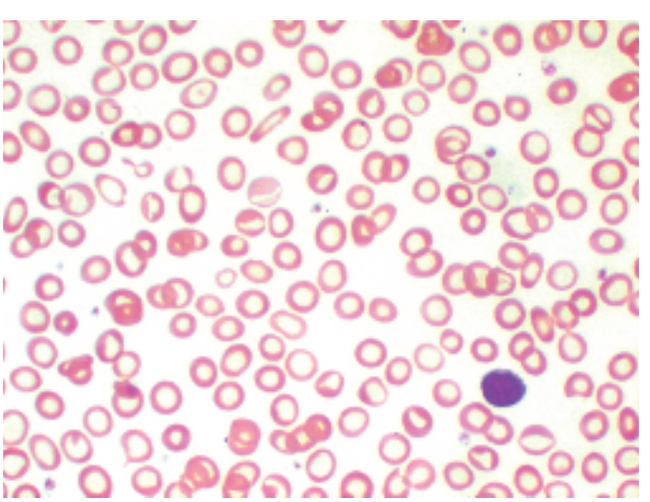


Figure 10-12 Iron-deficiency anemia. Red cells are small (microcytic) and are lacking in hemoglobin (hypochromic).

- **Pernicious anemia** is a specific form of B_{12} deficiency. It results from the lack of **intrinsic factor** (IF), a substance produced in the stomach that aids in the absorption of B_{12} from the intestine. Pernicious anemia must be treated with regular injections of B_{12}.
- In **sideroblastic anemia,** there is adequate iron available, but the iron is not used properly to manufacture hemoglobin. This disorder may be hereditary or acquired, as by exposure to toxins or drugs, or as secondary to another disease. The excess iron precipitates out in immature red cells (normoblasts).

Anemia Due to Loss or Destruction of Red Cells

- **Hemorrhagic anemia** results from blood loss. This may be a sudden loss, as from injury, or loss from chronic internal bleeding, as from the digestive tract in cases of ulcers or cancer.
- **Thalassemia** is a hereditary disease that appears mostly in Mediterranean populations. It causes production of abnormal hemoglobin and **hemolysis** (destruction) of red cells. Thalassemia is designated as α (alpha) or β (beta), according to the part of the molecule affected. Severe β thalassemia is also called **Cooley anemia.**
- In **sickle cell anemia,** a mutation alters the hemoglobin molecule so that it precipitates when it gives up oxygen and distorts the red blood cells into a crescent shape (Fig. 10-13). The altered cells block small blood vessels and deprive tissues of oxygen, an episode termed *sickle cell crisis*. The misshapen cells are also readily destroyed (hemolysed). The disease predominates in black populations. Genetic carriers of the defect, those with one normal and one abnormal gene, show *sickle cell trait*. They usually have no symptoms, except when oxygen is low, such as at high altitudes. They can, however, pass the defective gene to offspring. Sickle cell anemia, as well as many other genetic diseases, can be diagnosed in carriers and in the fetus before birth.

Reticulocyte counts are useful in diagnosing the causes of anemia. Reticulocytes are immature red blood cells that normally appear as a small percentage of the total erythrocytes. An increase in the number of reticulocytes indicates increased red-cell formation, as in response to hemorrhage or cell destruction. A decrease in reticulocytes indicates a failure in red-cell production, as caused by nutritional deficiency or aplastic anemia (see Box 10-6).

Coagulation Disorders

The most common cause of coagulation problems is a deficiency in the number of circulating platelets, a condition termed **thrombocytopenia.** Possible causes include aplastic anemia, infections, cancer of the bone marrow, and agents that destroy bone marrow, such as x-rays or certain drugs. This disorder results in bleeding into the skin and mucous membranes, variously described as **petechiae** (pinpoint spots), **ecchymoses** (bruises), and **purpura** (purple lesions).

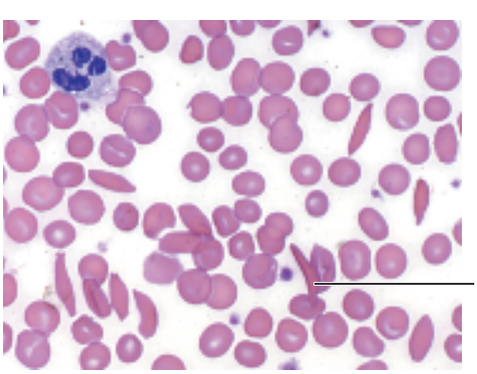
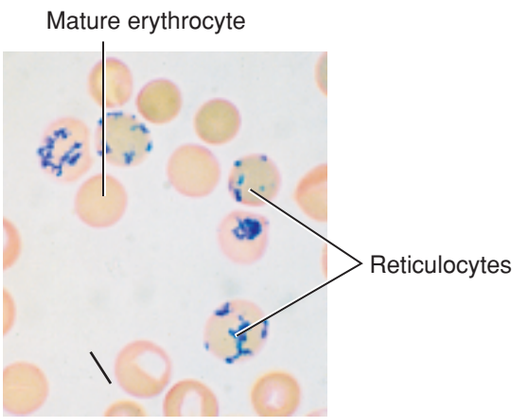


Figure 10-13 Sickle cell anemia. A blood smear shows sickled red cells, which take on a crescent shape when they give up oxygen.

Box 10•6 Clinical Perspectives — *Use of Reticulocytes in Diagnosis*

As erythrocytes mature in the red bone marrow, they go through a series of stages in which they lose their nucleus and most other organelles, maximising the space available to hold hemoglobin. In one of the last stages of development, small numbers of ribosomes and some rough endoplasmic reticulum remain in the cell and appear as a network, or reticulum, when stained. Cells at this stage are called reticulocytes. Reticulocytes leave the red bone marrow and enter the bloodstream, where they become fully mature erythrocytes in about 24 to 48 hours. The average number of red cells maturing through the reticulocyte stage at any given time is about 1% to 2%. Changes in these numbers can be used in diagnosing certain blood disorders.

When erythrocytes are lost or destroyed, as from chronic bleeding or some form of hemolytic anemia, red-cell production is "stepped up" to compensate for the loss. Greater numbers of reticulocytes are then released into the blood before reaching full maturity, and counts increase to above normal. On the other hand, a decrease in the number of circulating reticulocytes suggests a problem with red-cell production, as in cases of deficiency anemias or suppression of bone marrow activity.



Reticulocytes. Erythrocytes show a network in a late stage of development.

In **disseminated intravascular coagulation** (DIC) there is widespread clotting in the vessels, which obstructs circulation to the tissues. This is followed by diffuse hemorrhages as clotting factors are removed and the coagulation process is impaired. DIC may result from a variety of causes, including infection, cancer, hemorrhage, injury, and allergy.

Hemophilia is a hereditary deficiency of a specific clotting factor. It is a sex-linked disease that is passed from mother to son. There is bleeding into the tissues, especially into the joints (hemarthrosis). Hemophilia must be treated with transfusions of the necessary clotting factor.

Reference Box 10-7 lists tests done for these and other coagulation disorders.

Box 10•7 For Your Reference — *Coagulation Tests*

Test	Abbreviation	Description
Activated partial thromboplastin time	APTT	Measures time required for clot formation; used to evaluate clotting factors and monitor heparin therapy
Bleeding time	BT	Measures capacity of platelets to stop bleeding after a standard skin incision
Partial thromboplastin time	PTT	Evaluates clotting factors; similar to APTT, but less sensitive
Prothrombin time	PT, Pro Time	Indirectly measures prothrombin; used to monitor anticoagulant therapy. Quick test
Thrombin time (thrombin clotting time)	TT (TCT)	Measures how quickly a clot forms

Neoplasms

Leukemia is a neoplasm of white blood cells. The rapidly dividing but incompetent white cells accumulate in the tissues and crowd out the other blood cells. The symptoms of leukemia include anemia, fatigue, easy bleeding, **splenomegaly,** and sometimes hepatomegaly (enlargement of the liver). The causes of leukemia are unknown but may include exposure to radiation or harmful chemicals, hereditary factors, and perhaps viral infection.

The two main categories of leukemia based on origin and the cells involved are:

- Myelogenous leukemia, which originates in the bone marrow and involves mainly the granular leukocytes.
- Lymphocytic leukemia, which affects B cells and the lymphatic system, causing **lymphadenopathy** (lymph node disease) and adverse effects on the immune system.

Leukemias are further differentiated as acute or chronic based on clinical progress. Acute leukemia is the most common form of cancer in young children. The acute forms are:

- Acute myeloblastic (myelogenous) leukemia (AML). The prognosis in AML is poor for both children and adults.
- Acute lymphoblastic (lymphocytic) leukemia (ALL). With treatment, the remission rate is high for ALL.

The chronic forms of leukemia are:

- Chronic granulocytic leukemia, also called chronic myelogenous leukemia, which affects young to middle-aged adults. Most cases show the **Philadelphia chromosome (Ph),** an inherited anomaly in which part of chromosome 22 shifts to chromosome 9.
- Chronic lymphocytic leukemia (CLL), which appears mostly in the elderly and is the most slowly growing form of the disease (Fig. 10-14).

Treatment of leukemia includes chemotherapy, radiation therapy, and bone marrow transplantation. One advance in transplantation is the use of umbilical cord blood to replace blood-forming cells in bone marrow. This blood is more readily available than bone marrow and does not have to match as closely to avoid rejection.

Hodgkin disease is a disease of the lymphatic system that may spread to other tissues. It begins with enlarged but painless lymph nodes in the cervical (neck) region and then progresses to other nodes. A feature of Hodgkin disease is giant cells in the lymph nodes called **Reed–Sternberg cells** (Fig. 10-15). There are fever, night sweats, weight loss, and itching of the skin (pruritus). Persons of any age may be affected, but the disease predominates in young adults and those over age 50. Most cases can be cured with radiation and chemotherapy.

Non-Hodgkin lymphoma (NHL) is also a malignant enlargement of lymph nodes but does not show Reed–Sternberg cells. It is more common than Hodgkin disease and has a higher mortality rate. Cases vary in severity and prognosis. It is most prevalent in the older

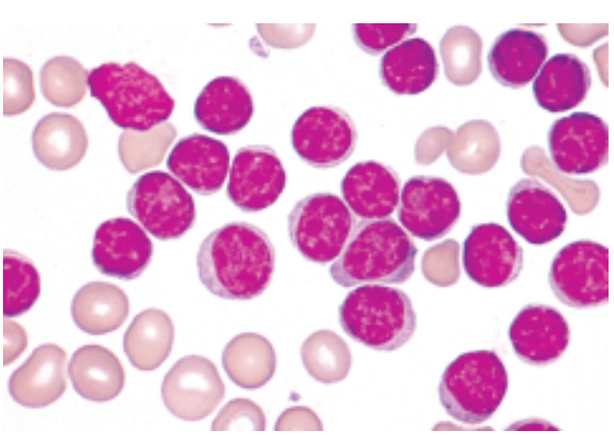


Figure 10-14 Chronic lymphocytic leukemia. A blood smear shows an above normal number of lymphocytes.

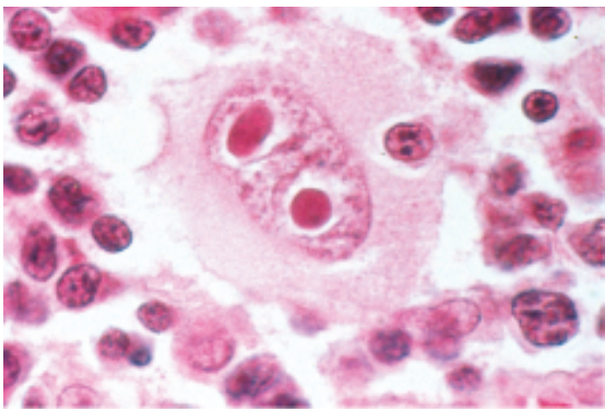


Figure 10-15 Reed–Sternberg cell. These cells are typical of Hodgkin disease.

adult population and in those with AIDS and other forms of immunodeficiency. NHL involves the T or B lymphocytes, and some cases may be related to infection with certain viruses. It requires systemic chemotherapy and, sometimes, bone marrow transplantation.

Multiple myeloma is a cancer of the blood-forming cells in bone marrow, mainly the plasma cells that produce antibodies. The disease causes anemia, bone pain, and weakening of the bones. Patients have a greater susceptibility to infection because of immunodeficiency. Abnormally high levels of calcium and protein in the blood often lead to kidney failure. Multiple myeloma is treated with radiation and chemotherapy, but the prognosis is generally poor.

Clinical Aspects of Immunity

Hypersensitivity

Hypersensitivity is a harmful overreaction of the immune system, commonly known as **allergy**. In cases of allergy, a person is more sensitive to a particular antigen than the average individual. Common **allergens** are pollen, animal dander, dust, and foods, but there are many more. A seasonal allergy to inhaled pollens is commonly called "hay fever." Responses may include itching, redness, or tearing of the eyes (conjunctivitis), skin rash, asthma, runny nose (rhinitis), sneezing, **urticaria** (hives), and **angioedema**, a reaction similar to hives but involving deeper layers of tissue.

An **anaphylactic reaction** is a severe generalised allergic response that can lead rapidly to death as a result of shock and respiratory distress. It must be treated by immediate administration of **epinephrine (adrenaline)** and maintenance of open airways. Oxygen, antihistamines, and corticosteroids may also be given. Common causes of anaphylaxis are drugs, especially penicillin and other antibiotics, vaccines, diagnostic chemicals, foods, and insect venom.

A **delayed hypersensitivity reaction** involves T cells and takes at least 12 hours to develop. A common example is the reaction to contact with plant irritants such as those of poison ivy and poison oak.

Immunodeficiency

The term **immunodeficiency** refers to any failure in the immune system. This may be congenital (present at birth) or acquired and may involve any components of the system. The deficiency may vary in severity but is always evidenced by an increased susceptibility to disease.

AIDS (acquired immunodeficiency syndrome) is acquired by infection with **HIV (human immunodeficiency virus)**, which attacks certain T cells. These cells have a specific surface attachment site, the CD4 receptor, for the virus. HIV is spread by sexual contact, use of contaminated needles, blood transfusions, and passage from an infected mother to a fetus. It leaves the host susceptible to opportunistic infections such as

pneumonia caused by the fungus *Pneumocystis jirovicii;* thrush, a fungal infection of the mouth caused by *Candida albicans;* and infection with *Cryptosporidium,* a protozoon that causes cramps and diarrhea. It also predisposes to **Kaposi sarcoma**, a once-rare form of skin cancer. AIDS may also induce autoimmunity or attack the nervous system.

AIDS is diagnosed and monitored by **CD4+ T lymphocyte counts**, a measure of cells with the HIV receptor. A count of less than 200 per µL of blood signifies severe immunodeficiency. HIV antibody levels and direct viral blood counts are also used to track the disease's course. At present there is no vaccine or cure for AIDS, but some drugs can delay its progress.

Autoimmune Diseases

A disorder that results from an immune response to one's own tissues is classified as an **autoimmune disease**. The cause may be a failure in the immune system or a reaction to body cells that have been slightly altered by mutation or disease. The list of diseases that are believed to be caused, at least in part, by autoimmunity is long. Some, such as **systemic lupus erythematosus** (SLE), **systemic sclerosis** (scleroderma), and **Sjögren syndrome**, affect tissues in multiple systems. Others target more specific organs or systems. Examples are pernicious anemia, rheumatoid arthritis, Graves disease (of the thyroid), myasthenia gravis (a muscle disease), fibromyalgia syndrome (a musculoskeletal disorder), rheumatic heart disease, and glomerulonephritis (a kidney disease). These diseases are discussed in more detail in other chapters.

TERMINOLOGY Key Terms

DISORDERS

AIDS (acquired immunodeficiency syndrome)	Failure of the immune system caused by infection with HIV (human immunodeficiency virus). The virus infects certain T cells and thus interferes with immunity.
allergen *AL-er-jen*	A substance that causes an allergic response
allergy *AL-er-jē*	Hypersensitivity
anaphylactic reaction *an-a-fi-LAK-tik*	An exaggerated allergic reaction to a foreign substance (root *phylaxis* means . "protection"). It may lead to death caused by circulatory collapse, and respiratory distress if untreated. Also called *anaphylaxis*
anemia *a-NĒ-mē-a*	A deficiency in the amount of hemoglobin in the blood; may result from blood loss, malnutrition, a hereditary defect, environmental factors, and other causes (see Figs. 10-12 and 10-13)
angioedema *an-jē-ō-e-DĒ-ma*	A localised edema with large hives (wheals) similar to urticaria but involving deeper layers of the skin and subcutaneous tissue
aplastic anemia *ā-PLAS-tik*	Anemia caused by bone marrow failure resulting in deficient blood-cell production, especially of red cells; pancytopenia
autoimmune disease *aw-tō-i-MŪN*	A condition in which the immune system produces antibodies against an individual's own tissues (prefix *auto* means "self")
Cooley anemia	A form of thalassemia (hereditary anemia) in which the B (beta) chain of hemoglobin is abnormal

TERMINOLOGY Key Terms

Continued

delayed hypersensitivity reaction	An allergic reaction involving T cells that takes at least 12 hours to develop. Examples are various types of contact dermatitis, such as poison ivy or poison oak; the tuberculin reaction (test for TB); and rejections of transplanted tissue.
disseminated intravascular coagulation (DIC)	Widespread formation of clots in the microscopic vessels; may be followed by bleeding caused by depletion of clotting factors
ecchymosis *ek-i-MŌ-sis*	A collection of blood under the skin caused by leakage from small vessels (root *chym* means "juice")
hemolysis *hē-MOL-i-sis*	The rupture of red blood cells and the release of hemoglobin (adjective: hemolytic)
hemophilia *hē-mō-FIL-ē-a*	A hereditary blood disease caused by lack of a clotting factor and resulting in abnormal bleeding
HIV (human immunodeficiency virus)	The virus that causes AIDS; human immunodeficiency virus
Hodgkin disease	A neoplastic disease of unknown cause that involves the lymph nodes, spleen, liver, and other tissues; characterised by the presence of giant Reed-Sternberg cells (see Fig. 10-15)
hypersensitivity	An immunologic reaction to a substance that is harmless to most people; allergy
immunodeficiency *im-ū-nō-dē-FISH-en-sē*	A congenital or acquired failure of the immune system to protect against disease
intrinsic factor	A substance produced in the stomach that aids in the absorption of vitamin B_{12}, necessary for the manufacture of red blood cells. Lack of intrinsic factor causes pernicious anemia.
Kaposi sarcoma *KAP-ō-sē*	Cancerous lesion of the skin and other tissues, seen most often in patients with AIDS
leukemia *lū-KĒ-mē-a*	Malignant overgrowth of immature white blood cells; may be chronic or acute; may affect bone marrow (myelogenous leukemia) or lymphoid tissue (lymphocytic leukemia)
lymphadenopathy *limf-ad-en-OP-a-thē*	Any disease of the lymph nodes
multiple myeloma *mī-el-Ō-ma*	A tumor of the blood-forming tissue in bone marrow
non-Hodgkin lymphoma (NHL)	A widespread malignant disease of lymph nodes that involves lymphocytes. It differs from Hodgkin disease in that giant Reed-Sternberg cells are absent.
Philadelphia chromosome (Ph)	An abnormal chromosome found in the cells of most individuals with chronic granulocytic (myelogenous) leukemia

TERMINOLOGY Key Terms

Continued

pernicious anemia *per-NISH-us*	Anemia caused by failure of the stomach to produce intrinsic factor, a substance needed for the absorption of vitamin B_{12}. This vitamin is required for the formation of erythrocytes.
petechiae *pē-TĒ-kē-ē*	Pinpoint, flat, purplish-red spots caused by bleeding within the skin or mucous membrane (singular: petechia)
purpura *PUR-pū-ra*	A condition characterised by hemorrhages into the skin, mucous membranes, internal organs, and other tissues (from Greek word meaning "purple"). Thrombocytopenic purpura is caused by a deficiency of platelets.
sideroblastic anemia *sid-e-rō-BLAS-tik*	Anemia caused by inability to use available iron to manufacture hemoglobin. The excess iron precipitates in normoblasts (developing red blood cells)
Sjögren syndrome *SHŌ-gren*	An autoimmune disease involving dysfunction of the exocrine glands and affecting secretion of tears, saliva, and other body fluids. Deficiency leads to dry mouth, tooth decay, corneal damage, eye infections, and difficulty in swallowing.
sickle cell anemia	A hereditary anemia caused by the presence of abnormal hemoglobin. Red blood cells become sickle-shaped and interfere with normal blood flow to the tissues (see Fig. 10-13). Most common in black populations of West African descent.
splenomegaly *splen-ō-MEG-a-lē*	Enlargement of the spleen
systemic lupus erythematosus *LŪ-pus er-i-thē-ma-TŌ-sus*	Inflammatory disease of connective tissue affecting the skin and multiple organs. Patients are sensitive to light and may have a red butterfly-shaped rash over the nose and cheeks.
systemic sclerosis	A diffuse disease of connective tissue that may involve any system causing inflammation, degeneration, and fibrosis. Also called scleroderma because it causes thickening of the skin.
thalassemia *thal-a-SĒ-mē-a*	A group of hereditary anemias mostly found in populations of Mediterranean descent (the name comes from the Greek word for "sea").
thrombocytopenia *throm-bō-sī-tō-PĒ-nē-a*	A deficiency of thrombocytes (platelets) in the blood
urticaria *ur-ti-KAR-ē-a*	A skin reaction consisting of round, raised eruptions (wheals) with itching; hives

DIAGNOSIS AND TREATMENT

adrenaline *a-DREN-a-lin*	See epinephrine
CD4+ T lymphocyte count	A count of the T cells that have the CD4 receptors for the AIDS virus (HIV). A count of less than 200/μL of blood signifies severe immunodeficiency.

TERMINOLOGY Key Terms

Continued

epinephrine *ep-i-NEF-rin*	A powerful stimulant produced by the adrenal gland and sympathetic nervous system. Activates the cardiovascular, respiratory, and other systems needed to meet stress. Used as a drug to treat severe allergic reactions and shock. Also called adrenaline.
reticulocyte counts *re-TIK-ū-lō-sīt*	Blood counts of reticulocytes, a type of immature red blood cell; reticulocyte counts are useful in diagnosis to indicate the rate of erythrocyte formation (see Box 10-6)
Reed-Sternberg cells	Giant cells that are characteristic of Hodgkin disease. They usually have two large nuclei and are surrounded by a halo (see Fig 10-15).

Go to the pronunciation glossary in Chapter 10 on the CD-ROM to hear these words pronounced.

TERMINOLOGY Supplementary Terms

NORMAL STRUCTURE AND FUNCTION

agglutination *a-glū-ti-NĀ-shun*	The clumping of cells or particles in the presence of specific antibodies
bilirubin *bil-i-RŪ-bin*	A pigment derived from the breakdown of hemoglobin. It is eliminated by the liver in bile.
complement *COM-ple-ment*	A group of plasma enzymes that interacts with antibodies
corpuscle *KOR-pus-l*	A small mass or body. A blood corpuscle is a blood cell.
hemopoietic stem cell *hē-mō-poy-E-tik*	A primitive bone marrow cell that gives rise to all varieties of blood cells
heparin *HEP-a-rin*	A substance found throughout the body that inhibits blood coagulation; an anticoagulant
plasmin *PLAZ-min*	An enzyme that dissolves clots; also called *fibrinolysin*
thrombin *THROM-bin*	The enzyme derived from prothrombin that converts fibrinogen to fibrin

TERMINOLOGY Supplementary Terms

Continued

SYMPTOMS AND CONDITIONS

agranulocytosis *ā-gran-ū-lō-sī-TŌ-sis*	A condition involving a decrease in the number of granulocytes in the blood; also called *granulocytopenia*
erythrocytosis *e-rith-rō-sī-TŌ-sis*	Increase in the number of red cells in the blood; may be normal, such as to compensate for life at high altitudes, or abnormal, such as in cases of pulmonary or cardiac disease
Fanconi syndrome *fan-KŌ-nē*	Congenital aplastic anemia that appears between birth and 10 years of age; may be hereditary or caused by damage before birth, as by a virus
graft-versus-host reaction (GVHR)	An immunologic reaction of transplanted lymphocytes against tissues of the host; a common complication of bone marrow transplantation.
hairy-cell leukemia	A form of leukemia in which cells have filaments, making them look "hairy"
hematoma *hē-ma-TŌ-ma*	A localised collection of blood, usually clotted, caused by a break in a blood vessel
hemolytic disease of the newborn (HDN)	Disease that results from incompatibility between the blood of a mother and her fetus, usually involving Rh factor. An Rh-negative mother produces antibody to an Rh-positive fetus that, in later pregnancies, will destroy the red cells of an Rh-positive fetus. The problem is usually avoided by treating the mother with antibodies to remove the Rh antigen; erythroblastosis fetalis
hemosiderosis *hē-mō-sid-er-Ō-sis*	A condition involving the deposition of an iron-containing pigment (hemosiderin) mainly in the liver and the spleen. The pigment comes from hemoglobin released from disintegrated red blood cells.
idiopathic thrombocytopenic purpura (ITP)	A clotting disorder caused by destruction of platelets that usually follows a viral illness. Causes petechiae and hemorrhages into the skin and mucous membranes.
infectious mononucleosis *mon-ō-nū-klē-Ō-sis*	An acute infectious disease caused by Epstein–Barr virus (EBV). Characterised by fever, weakness, lymphadenopathy, hepatosplenomegaly, and atypical lymphocytes (resembling monocytes) (Fig. 10-16).
lymphocytosis *limf-ō-sī-TŌ-sis*	An increase in the number of circulating lymphocytes
myelodysplastic syndrome *mī-el-ō-dis-PLAS-tik*	Bone marrow dysfunction resulting in anemia and deficiency of neutrophils and platelets. May develop in time into leukemia; preleukemia
myelofibrosis *mī-el-ō-fī-BRŌ-sis*	Condition in which bone marrow is replaced with fibrous tissue
neutropenia *nū-trō-PĒ-nē-a*	A decrease in the number of neutrophils with increased susceptibility to infection. Causes include drugs, irradiation, and infection. May be a side effect of treatment for malignancy.
pancytopenia *pan-sī-tō-PĒ-nē-a*	A decrease in all cells of the blood, as in aplastic anemia

TERMINOLOGY — Supplementary Terms

Continued

polycythemia *pol-ē-sī-THĒ-mē-a*	Any condition in which there is a relative increase in the percent of red blood cells in whole blood. May result from excessive production of red cells because of lack of oxygen, as caused by high altitudes, breathing obstruction, heart failure, or certain forms of poisoning. Apparent polycythemia results from concentration of the blood, as by dehydration.
polycythemia vera *pol-ē-sī-THĒ-mē-a VĒ-ra*	A condition in which overactive bone marrow produces too many red blood cells. These interfere with circulation and promote thrombosis and hemorrhage. Treated by blood removal. Also called *erythremia, Vaquez–Osler disease.*
septicemia *sep-ti-SĒ-mē-a*	Presence of microorganisms in the blood
spherocytic anemia *sfēr-ō-SIT-ik*	Hereditary anemia in which red blood cells are round instead of disk-shaped and rupture (hemolyse) excessively
thrombotic thrombocytopenic purpura (TTP)	An often-fatal disorder in which multiple clots form in blood vessels
von Willebrand disease	A hereditary bleeding disease caused by lack of von Willebrand factor, a substance necessary for blood clotting

DIAGNOSIS (see also Boxes 10–4 and 10–7)

Bence Jones protein	A protein that appears in the urine of patients with multiple myeloma
Coombs test	A test for detection of antibodies to red blood cells such as appear in cases of autoimmune hemolytic anemias
electrophoresis *ē-lek-trō-for-Ē-sis*	Separation of particles in a liquid by application of an electrical field; used to separate components of blood.
ELISA	Enzyme-linked immunosorbent assay. A highly sensitive immunologic test used to diagnose HIV infection, hepatitis, and Lyme disease, among others.
monoclonal antibody *mon-ō-KLŌ-nal*	A pure antibody produced in the laboratory; used for diagnosis and treatment
pH	A scale that measures the relative acidity or alkalinity of a solution. Represents the amount of hydrogen ion in the solution.
Schilling test *SHIL-ing*	Test used to determine absorption of vitamin B_{12} by measuring excretion of radioactive B_{12} in the urine. Used to distinguish pernicious from nutritional anemia.
seroconversion *sēr-ō-con-VER-zhun*	The appearance of antibodies in the serum in response to a disease or an immunisation
Western blot assay	A very sensitive test used to detect small amounts of antibodies in the blood
Wright stain	A commonly used blood stain. Figure 10-2 shows blood cells stained with Wright stain.

TERMINOLOGY Supplementary Terms

Continued

TREATMENT

anticoagulant *an-tē-kō-AG-ū-lant*	An agent that prevents or delays blood coagulation
antihistamine *an-tē-HIS-ta-mēn*	A drug that counteracts the effects of histamine and is used to treat allergic reactions
apheresis *ā-fer-Ē-sis*	A procedure in which blood is withdrawn, a portion is separated and retained, and the remainder is returned to the donor. Apheresis may be used as a suffix with a root meaning the fraction retained, such as plasmapheresis, leukapheresis.
autologous blood *aw-TOL-ō-gus*	A person's own blood. May be donated in advance of surgery and transfused if needed.
cryoprecipitate *krī-ō-prē-SIP-i-tāt*	A sediment obtained by cooling. The fraction obtained by freezing blood plasma contains clotting factors.
desensitisation *dē-sen-si-tī-SĀ-shun*	Treatment of allergy by small injections of the offending allergen. This causes an increase of antibody to destroy the antigen rapidly on contact.
homologous blood *hō-MOL-ō-gus*	Blood from animals of the same species, such as human blood used for transfusion from one person to another. Blood used for transfusions must be compatible with the blood of the recipient.
immunosuppression *im-ū-nō-sū-PRESH-un*	Depression of the immune response. May be correlated with disease but also may may be induced therapeutically to prevent rejection in cases of tissue transplantation.
protease inhibitor *PRŌ-tē-ās*	An anti-HIV drug that acts by inhibiting an enzyme the virus needs to multiply

Go to the pronunciation glossary in Chapter 10 on the CD-ROM to hear these words pronounced.

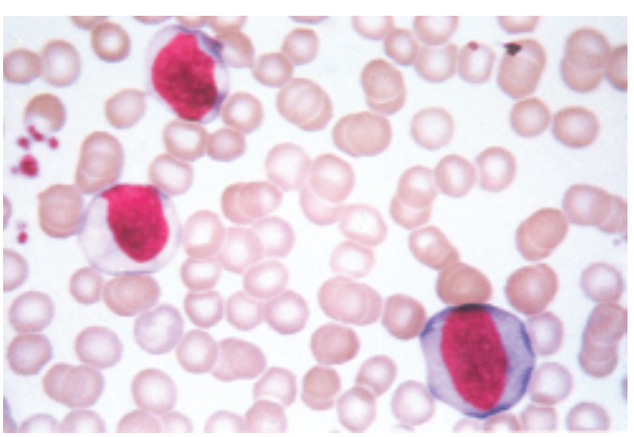


Figure 10-16 Infectious mononucleosis. Atypical lymphocytes characterise this viral disease.

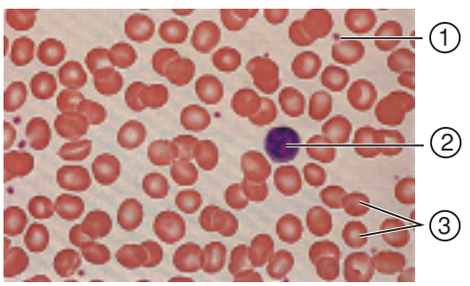
TERMINOLOGY Abbreviations

Ab	Antibody
Ag	Antigen
AIDS	Acquired immunodeficiency syndrome
ALL	Acute lymphoblastic (lymphocytic) leukemia
AML	Acute myeloblastic (myelogenous) leukemia
APTT	Activated partial thromboplastin time
BT	Bleeding time
CBC	Complete blood count
CLL	Chronic lymphocytic leukemia
CML	Chronic myelogenous leukemia
crit	Hematocrit
DIC	Disseminated intravascular coagulation
Diff	Differential count
EBV	Epstein–Barr virus
ELISA	Enzyme-linked immunosorbent assay
EPO	Erythropoietin
ESR	Erythrocyte sedimentation rate
FFP	Fresh frozen plasma
Hb, Hgb	Hemoglobin
Hct, Ht	Hematocrit
HDN	Hemolytic disease of the newborn
HIV	Human immunodeficiency virus
IF	Intrinsic factor
Ig	Immunoglobulin
ITP	Idiopathic thrombocytopenic purpura
lytes	Electrolytes
MCH	Mean corpuscular hemoglobin
MCHC	Mean corpuscular hemoglobin concentration
mcL	Microlitre
MCV	Mean corpuscular volume
MDS	Myelodysplastic syndrome
mEq	Milliequivalent
NHL	Non-Hodgkin lymphoma
PCV	Packed cell volume
pH	Scale for measuring hydrogen ion concentration (acidity or alkalinity)
Ph	Philadelphia chromosome
PMN	Polymorphonuclear (neutrophil)
poly	Neutrophil
polymorph	Neutrophil
PT	Pro time; prothrombin time
PTT	Partial thromboplastin time
RBC	Red blood cell; red-blood-cell count
seg	Neutrophil
SLE	Systemic lupus erythematosus
T(C)T	Thrombin (clotting) time
TTP	Thrombotic thrombocytopenic purpura
vWF	von Willebrand factor
WBC	White blood cell; white blood (cell) count

CHAPTER REVIEW

LABELING EXERCISE
Blood Cells

Write the name of each numbered part on the corresponding line of the answer sheet.



Erythrocyte **1.** _____

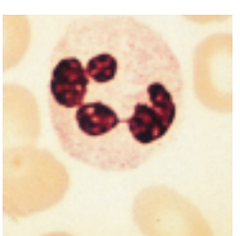
Leukocyte **2.** _____

Platelet **3.** _____

Leukocytes (white blood cells)

Write the name of each numbered part on the corresponding line of the answer sheet.

Leukocytes (white blood cells)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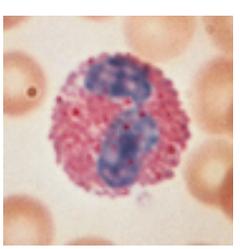
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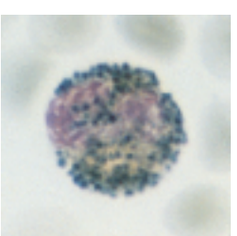
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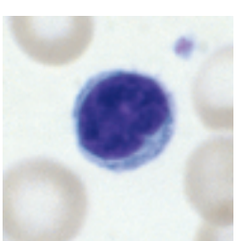
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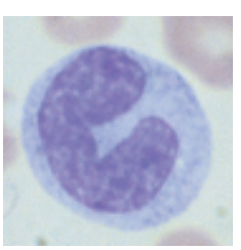
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Basophil **1.** _____

Eosinophil **2.** _____

Lymphocyte **3.** _____

Monocyte **4.** _____

Neutrophil **5.** _____

TERMINOLOGY

Match the following terms and write the appropriate letter to the left of each number:

_____	**1.** myelogenic	**a.** immature bone marrow cell
_____	**2.** leukopenia	**b.** originating in bone marrow
_____	**3.** leukemia	**c.** malignant overgrowth of white blood cells
_____	**4.** myeloblast	**d.** formation of white blood cells
_____	**5.** leukopoiesis	**e.** deficiency of white blood cells
_____	**6.** calcidiol	**a.** pertaining to iron
_____	**7.** hypokalemia	**b.** urinary excretion of nitrogenous compounds
_____	**8.** ferrous	**c.** hormone involved in the metabolism of calcium
_____	**9.** siderosis	**d.** decreased potassium in the blood
_____	**10.** azoturia	**e.** condition involving iron deposits
_____	**11.** thalassemia	**a.** hives
_____	**12.** petechiae	**b.** hereditary form of anemia
_____	**13.** urticaria	**c.** stoppage of blood flow
_____	**14.** hemophilia	**d.** hereditary clotting disorder
_____	**15.** hemostasis	**e.** pinpoint spots caused by bleeding into the skin
_____	**16.** pH	**a.** hematocrit
_____	**17.** HIV	**b.** scale for measuring acidity or alkalinity
_____	**18.** CLL	**c.** hormone that stimulates red blood cell formation
_____	**19.** PCV	**d.** a form of leukemia
_____	**20.** EPO	**e.** virus that causes an immunodeficiency disease

Supplementary Terms

_____	**21.** electrophoresis	**a.** separation of blood and use of components
_____	**22.** heparin	**b.** pigment that comes from hemoglobin
_____	**23.** apheresis	**c.** anticoagulant
_____	**24.** ELISA	**d.** method for separating components of a solution
_____	**25.** bilirubin	**e.** sensitive immunologic test

Fill in the blanks:

26. The engulfing of foreign material by white cells is called _____.

27. The iron-containing pigment in red blood cells that carries oxygen is called _____.

28. A substance that separates into ions in solution is a(n) _____.

29. The cells fragments active in blood clotting are the _____.

30. A substance that induces the formation of antibodies is a(n) _____.

31. A hemocytometer is used to count _____.

32. Oxyhemoglobin is hemoglobin combined with _____.
33. A hematoma is a localised collection of _____.
34. A disorder involving lack of hemoglobin in the blood is _____.
35. A myeloma is a neoplasm that involves the _____.

True–False. Examine the following statements. If the statement is true, write T in the first blank. If the statement is false, write F in the first blank and correct the statement by replacing the underlined word in the second blank.

36. A platelet is also called a lymphocyte. _____ _____
37. A plasma cell produces antibodies. _____ _____
38. The liquid that remains after blood coagulates is called serum _____ _____
39. Blood that reacts with both A and B antisera is type AB. _____ _____
40. A band cell is an immature monocyte. _____ _____
41. The root natri- pertains to sodium. _____ _____

The suffixes *-ia, -osis,* and *-hemia* all denote an increase in the type of cell indicated by the word root. Define the following terms:

42. eosinophilia *(ē-ō-sin-ō-FIL-ē-a)* _____
43. *erythrocytosis (e-rith-rō-sī-TŌ-sis)* _____
44. *thrombocythemia (throm-bō-sī-THĒ-mē-a)* _____
45. *neutrophilia (nū-trō-FIL-ē-a)* _____
46. *monocytosis (mon-ō-sī-TŌ-sis)* _____

Word building. Write a word for each of the following:

47. An immature lymphocyte _____
48. A decrease in the number of platelets (thrombocytes) in the blood _____
49. Formation of white blood cells _____
50. Presence of pus in the blood _____
51. Specialist in the study of immunity _____
52. Profuse flow of blood _____

Adjectives. Use the ending *-ic* to write the adjective form of the following words:

53. basophil _____
54. lymphocyte _____
55. leukemia _____
56. septicemia _____
57. hemolysis _____
58. thrombosis _____

Define each of the following:

59. myelotoxin _____
60. viremia _____

61. neutropenia _____

62. autoimmunity _____

63. hypoxemia _____

Eliminations. In each of the sets below, underline the word that does not fit in with the rest and explain the reason for your choice:

64. fibrin - thrombin - thrombolysis - prothrombin - fibrinogen

_____

65. Diff - Hct - CBC - CD4 - ESR

_____

66. eosinophil - reticulocyte - monocyte - basophil - lymphocyte

_____

67. allergy - hypersensitivity - immunodeficiency - antigen - anaphylaxis

_____

Word analysis. Define the following words, and give the meaning of the word parts in each. Use a dictionary if necessary.

68. Polycythemia (*pol-ē-sī-THĒ-mē-a)* _____

    a. poly _____

    b. cyt/o _____

    c. hem _____

    d. -ia _____

69. Hemochromatosis *(hē-mō-krō-mā-TŌ-sis)* _____

    a. hem/o _____

    b. chromat/o _____

    c. -sis _____

70. Anisocytosis *(an-ī-sō-sī-TŌ-sis)* _____

    a. an- _____

    b. iso- _____

    c. cyt/o _____

    d. -sis _____

71. Myelodysplastic *(mī-el-ō-dis-PLAS-tik)* _____

    a. myel/o _____

    b. dys- _____

    c. plast(y) _____

    d. -ic _____

Go to the word exercises in Chapter 10 on the CD-ROM for additional review exercises.

CASE STUDIES

CASE STUDY 10–1: Latex Allergy

M.R., a 36-year-old registered nurse (RN), was diagnosed 7 years ago with latex allergy. She first noticed that contact dermatitis developed when she wore powdered latex gloves. Tachycardia, hypotension, bronchospasm, urticaria, and rhinitis soon developed with contact or proximity to latex in surgery. She had one frightening episode of anaphylaxis. Her allergy is of the type I hypersensitivity, IgE T-cell-mediated latex allergy, which was diagnosed by both a radioallergosorbent test (RAST) and a skin-prick test.

M.R. avoids all contact with any natural rubber latex in her home and at work. She can work only in a pediatric OR because they are latex-free, since many children with congenital disorders are allergic to latex. She wears a medical alert bracelet, uses a bronchodilator inhaler at the first symptom of bronchospasm, and carries a syringe of epinephrine at all times.

CASE STUDY 10–2: Blood Replacement

C.L., a 16-year-old girl, sustained a ruptured liver when she hit a tree while sledding. Emergency surgery was needed to stop the internal bleeding. During surgery, the ruptured segment of the liver was removed and the laceration was sutured with a heavy, absorbable suture on a large smooth needle. Before surgery, her hemoglobin was 10.2 g/dL, but the reading decreased to 7.6 g/dL before hemostasis was attained. Cell salvage, or autotransfusion, was set up. In this procedure, the free blood was suctioned from her abdomen and mixed with an anticoagulant (heparin). The RBCs were washed in a sterile centrifuge with NSS and transfused back to her through tubing fitted with a filter. She also received 6 units of homologous, leukocyte-reduced whole blood, 5 units of fresh frozen plasma, and 2 units of platelets. During the surgery, the anesthetist repeatedly tested her Hgb and Hct as well as prothrombin time and partial thromboplastin time to monitor her clotting mechanisms.

C.L. is B-positive. Fortunately, there was enough B-positive blood in the hospital blood bank for her surgery. The lab informed her surgeon that they had 2 units of B-negative and 6 units of O-negative blood, which she could have received safely if she needed more blood during the night. However, her hemoglobin level increased to 12 g/dL, and she was stable during her recovery. She was monitored for DIC and pulmonary emboli.

CASE STUDY 10–3: Myelofibrosis

A.Y., a 52-year-old kindergarten teacher, had myelofibrosis that had been in remission for 25 years. She had seen her hematologist regularly and had had routine blood testing since the age of 27. After several weeks of fatigue, idiopathic joint and muscle aching, weakness, and a frightening episode of syncope, she saw her hematologist for evaluation. Her hemoglobin was 9.0 g/dL and her hematocrit was 29%. Concerned that she was having an exacerbation, her doctor scheduled a bone marrow aspiration, and the results were positive for myelofibrosis.

A.Y. went through a 6-month therapy regimen of iron supplements in the form of ferrous sulfate tablets and received weekly vitamin B_{12} injections. Interferon was given every other week in addition to erythropoiesis therapy, which was unsuccessful. She was treated for presumed aplastic anemia. During treatment, splenomegaly developed, which compromised her abdominal organs and pulmonary function. She continued to lose weight, and her hemoglobin dropped as low as 6.0 g/dL. Weekly transfusions of packed RBCs did not improve her hemoglobin and hematocrit.

After a regimen of high-dose chemotherapy to shrink the fibres in her bone marrow and a splenectomy, A.Y. received a stem-cell transplant. The stem cells were obtained from blood donated by her brother, who was a perfect immunologic match. After a 6-month period of recovery in a protected environment, required because of her immunocompromised state, A.Y. returned home and has been free of disease symptoms for over 1 year.

Continued

CASE STUDY QUESTIONS

Multiple choice. Select the best answer and write the letter of your choice to the left of each number:

_____ **1.** The natural latex protein in latex gloves may act as a(n):
- **a.** antibody
- **b.** allergen
- **c.** lymphocyte
- **d.** purpura
- **e.** immunocyte

_____ **2.** Urticaria is commonly called:
- **a.** rhinitis
- **b.** dermatitis
- **c.** hives
- **d.** ELISA
- **e.** congenital

_____ **3.** The cells involved in a T-cell-mediated allergic response are:
- **a.** basophils
- **b.** monocytes
- **c.** antigen
- **d.** T lymphocytes
- **e.** B cells

_____ **4.** Anaphylaxis, a life-threatening physiological response, is an extreme form of:
- **a.** remission
- **b.** hypersensitivity
- **c.** hemostasis
- **d.** exacerbation
- **e.** homeostasis

_____ **5.** The common name for epinephrine is:
- **a.** heparin
- **b.** adrenaline
- **c.** cortisone
- **d.** apheresis
- **e.** antihistamine

_____ **6.** The removal of part of the liver is called:
- **a.** partial hepatectomy
- **b.** hepatomegaly
- **c.** resection of the liver
- **d.** a and b
- **e.** a and c

_____ **7.** The unit for hemoglobin measurement (g/dL) means:
- **a.** grams in decimal point
- **b.** grains in a decathlon
- **c.** drops in 50 cc
- **d.** grams in 100 mL
- **e.** grains in decilitre

Continued

_____ **8.** Heparin, an anticoagulant, is a drug that:
- **a.** increases the rate of blood clotting
- **b.** takes the place of fibrin
- **c.** supports thrombin
- **d.** interferes with blood clotting
- **e.** makes blood thinner than water

_____ **9.** The RBCs were washed with NSS. This means: the _____ were washed with _____.
- **a.** reticulocytes, heparin
- **b.** red blood cells, nutritional solution
- **c.** erythrocytes, normal saline solution
- **d.** reticulocytes, normal simple solution
- **e.** red blood cells, heparin

_____ **10.** Autotransfusion is transfusion of autologous blood, that is, the patient's own blood. Homologous blood is taken from:
- **a.** another human
- **b.** synthetic chemicals
- **c.** plasma with clotting factors
- **d.** an animal with similar antibodies as humans
- **e.** IV fluid with electrolytes

_____ **11.** Patients who lose a significant amount of blood may lose clotting ability. Effective therapy in such cases would be replacement of:
- **a.** IV solution with electrolytes
- **b.** iron supplements
- **c.** platelets
- **d.** heparin
- **e.** packed RBCs

_____ **12.** C.L.'s blood type is B-positive. The best blood for her to receive is:
- **a.** positive
- **b.** negative
- **c.** AB-positive
- **d.** B-negative
- **e.** B-positive

_____ **13.** Myelofibrosis, like aplastic anemia, is a disease in which there is:
- **a.** overgrowth of RBCs
- **b.** destruction of the bone marrow
- **c.** dangerously high hemoglobin and hematocrit
- **d.** absence of bone marrow
- **e.** lymphatic tissue in the bone marrow

_____ **14.** Erythropoiesis is:
- **a.** production of blood
- **b.** production of red cells
- **c.** production of plasma
- **d.** destruction of white cells
- **e.** destruction of platelets

Continued

____ **15.** The "ferrous" in ferrous sulfate represents:
- **a.** electrolytes
- **b.** RBCs
- **c.** iron
- **d.** oxygen
- **e.** B vitamins

____ **16.** Hemoglobin and hematocrit values pertain to:
- **a.** leukocytes
- **b.** immune response
- **c.** granulocytes
- **d.** red blood cells
- **e.** fibrinogen

____ **17.** Splenomegaly is:
- **a.** prolapse of the spleen
- **b.** movement of the spleen
- **c.** enlargement of the lymph glands
- **d.** destruction of the bone marrow
- **e.** enlargement of the spleen

____ **18.** The stem cells A.Y. received were expected to develop into new:
- **a.** spleen cells
- **b.** bone marrow cells
- **c.** hemoglobin
- **d.** abdominal organs
- **e.** cartilage

____ **19.** A.Y.'s health was compromised because the high-dose chemotherapy caused:
- **a.** immunodeficiency
- **b.** electrolyte imbalance
- **c.** anoxia
- **d.** Rh incompatibility
- **e.** autoimmunity

Abbreviations. Define the following abbreviations:

20. Ig _____

21. Hgb _____

22. Hct _____

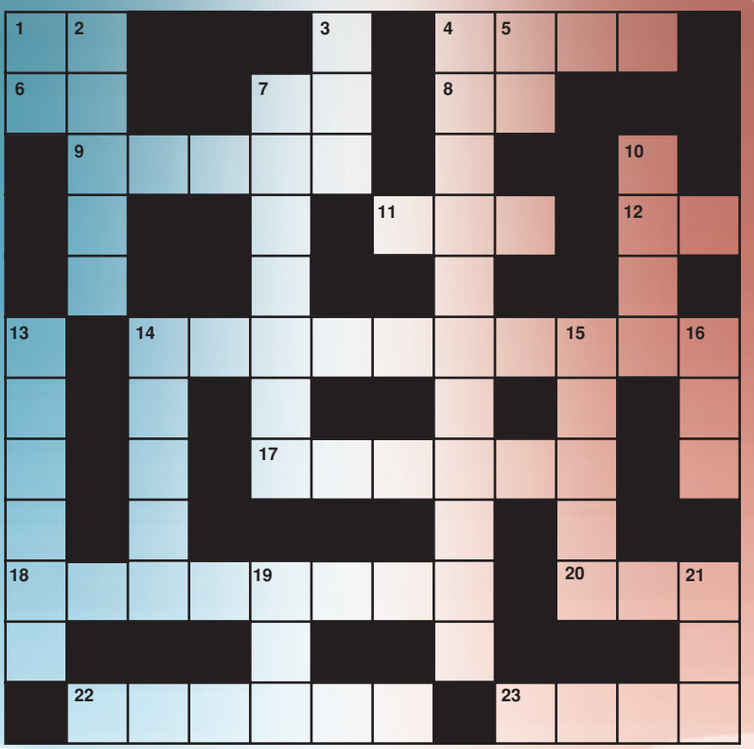
23. FFP _____

24. PT _____

25. PTT _____

26. DIC _____

Blood and Immunity



ACROSS

1. Alternative name for antibody (abbreviation)
4. Cold: prefix
6. Chemical symbol for sodium
7. Antibody (abbreviation)
8. Oxygen: root
9. Bone marrow: combining form
11. Oxygen-carrying pigment of red cells (abbreviation)
12. Antigen (abbreviation)
14. The substance that is deficient in cases of anemia
17. Most numerous type of white blood cell: combining form
18. Immature form of red blood cell: combining form
20. Type of widespread coagulation disorder (abbreviation)
22. Name used for a hereditary type of anemia
23. A mineral found in the blood (root)

DOWN

1. Prefix meaning "not"
2. Fraction of the blood that contains antibodies: _____ globulin
3. Common blood type system
4. Blood clotting
5. Prescription (abbreviation)
7. Protein found in the blood
10. Potassium: combining form
13. Iron: combining form
14. Blood: root
15. Fluid that brings oxygen and nutrients to the cells
16. New: prefix
19. Form of lymphocytic leukemia (abbreviation)
21. Comprehensive blood study (abbreviation)