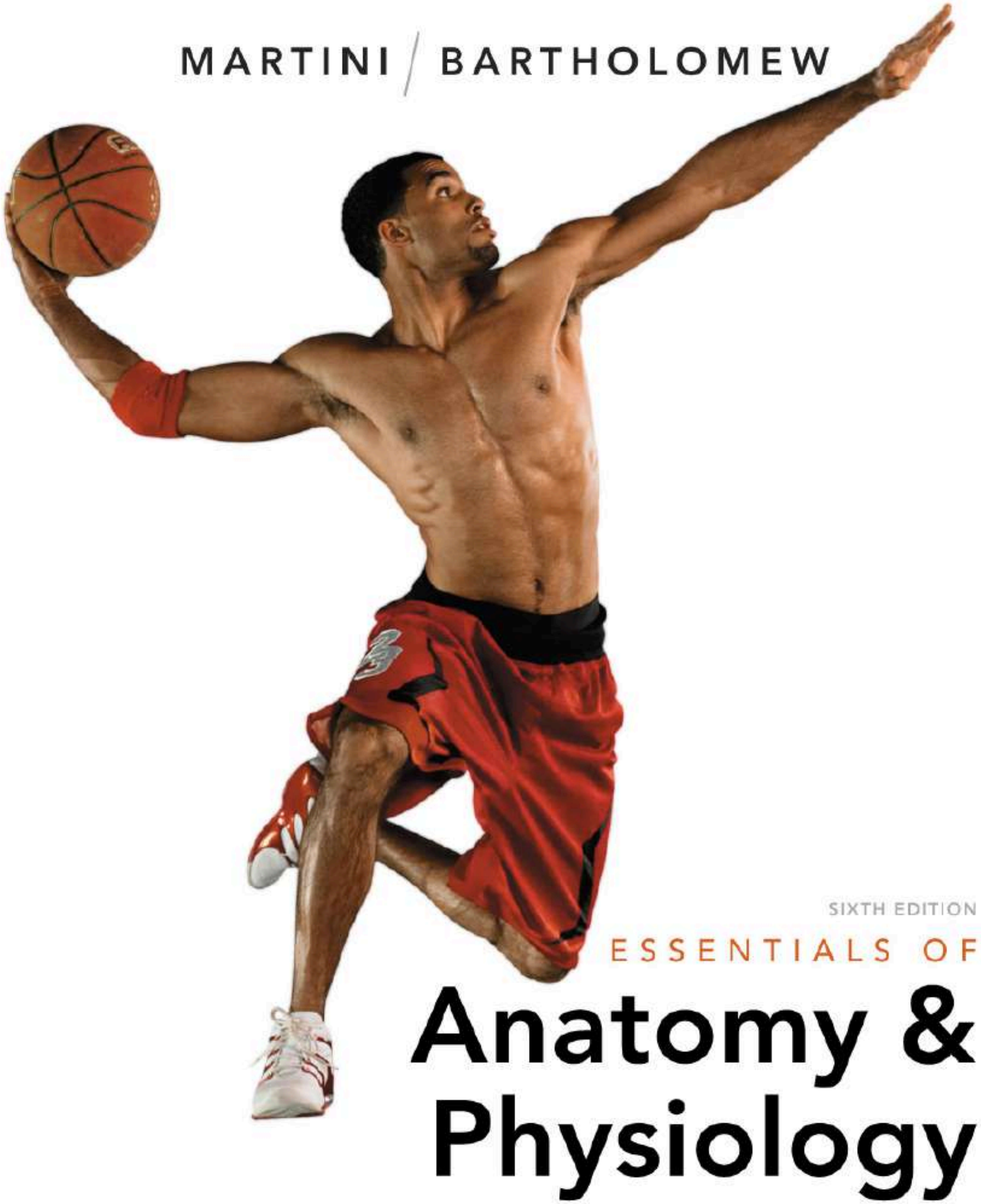

PowerPoint® Lecture Slides
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CHAPTER **11**

The Cardiovascular System: Blood

Chapter 11 Learning Outcomes

- 11-1
  - Describe the components and major functions of blood, and list the physical characteristics of blood.
- 11-2
  - Describe the composition and functions of plasma.
- 11-3
  - List the characteristics and functions of red blood cells, describe the structure and function of hemoglobin, indicate how red blood cell components are recycled, and explain erythropoiesis.
- 11-4
  - Discuss the factors that determine a person's blood type, and explain why blood typing is important.

Chapter 11 Learning Outcomes

- 11-5
  - Categorize the various white blood cells on the basis of their structures and functions, and discuss the factors that regulate their production.
- 11-6
  - Describe the structure, function, and production of platelets.
- 11-7
  - Describe the mechanisms that control blood loss after an injury.

Introduction to the Cardiovascular System (Introduction)

- Includes heart, blood vessels, and blood
- Major transportation system for:
  - Substances we need from the external environment
  - Substances we need to eliminate through wastes
  - Substances we synthesize that need delivery to other organs

Functions of Blood (11-1)

1. Transports dissolved gases, nutrients, hormones, and metabolic wastes
2. Regulates pH and ion makeup of interstitial fluids
3. Restricts fluid loss at injury sites
4. Defends against toxins and pathogens
5. Stabilizes body temperature

Composition of Blood (11-1)

- A liquid connective tissue made of plasma and formed elements
  - Temperature is 38°C, a little above body temperature
  - Blood is five times more viscous than water
    - Viscosity refers to thickness, stickiness
    - Caused by plasma proteins, formed elements
  - pH is slightly alkaline in a range of 7.35–7.45

Blood Collection and Analysis (11-1)

- Whole blood is usually collected from veins
  - Called **venipuncture**
  - Common site is median cubital vein
- Can also be collected from peripheral capillary
  - A drop from fingertip or earlobe
- Occasionally collected from **arterial puncture**
  - To evaluate gas exchange efficiency in lung function

Checkpoint (11-1)

1. List five major functions of blood.
2. What two components make up whole blood?
3. Why is venipuncture a common technique for obtaining a blood sample?

Plasma (11-2)

- Along with interstitial fluid, makes up most of ECF
- Contains:
  - Plasma proteins
  - Hormones
  - Nutrients
  - Gases
  - Water

Three Major Types of Plasma Proteins (11-2)

1. Albumins
   - Most abundant
   - Maintains osmotic pressure of plasma
2. Globulins
   - Act as transport proteins and antibodies
3. Fibrinogen
   - Functions in blood clotting, converting to **fibrin**

Plasma Proteins (11-2)

- Plasma, minus the clotting proteins like fibrinogen, is called **serum**
- 90 percent of plasma proteins are synthesized by liver
- Liver disorders can result in altered blood composition and function

Figure 11-1 The Composition of Whole Blood

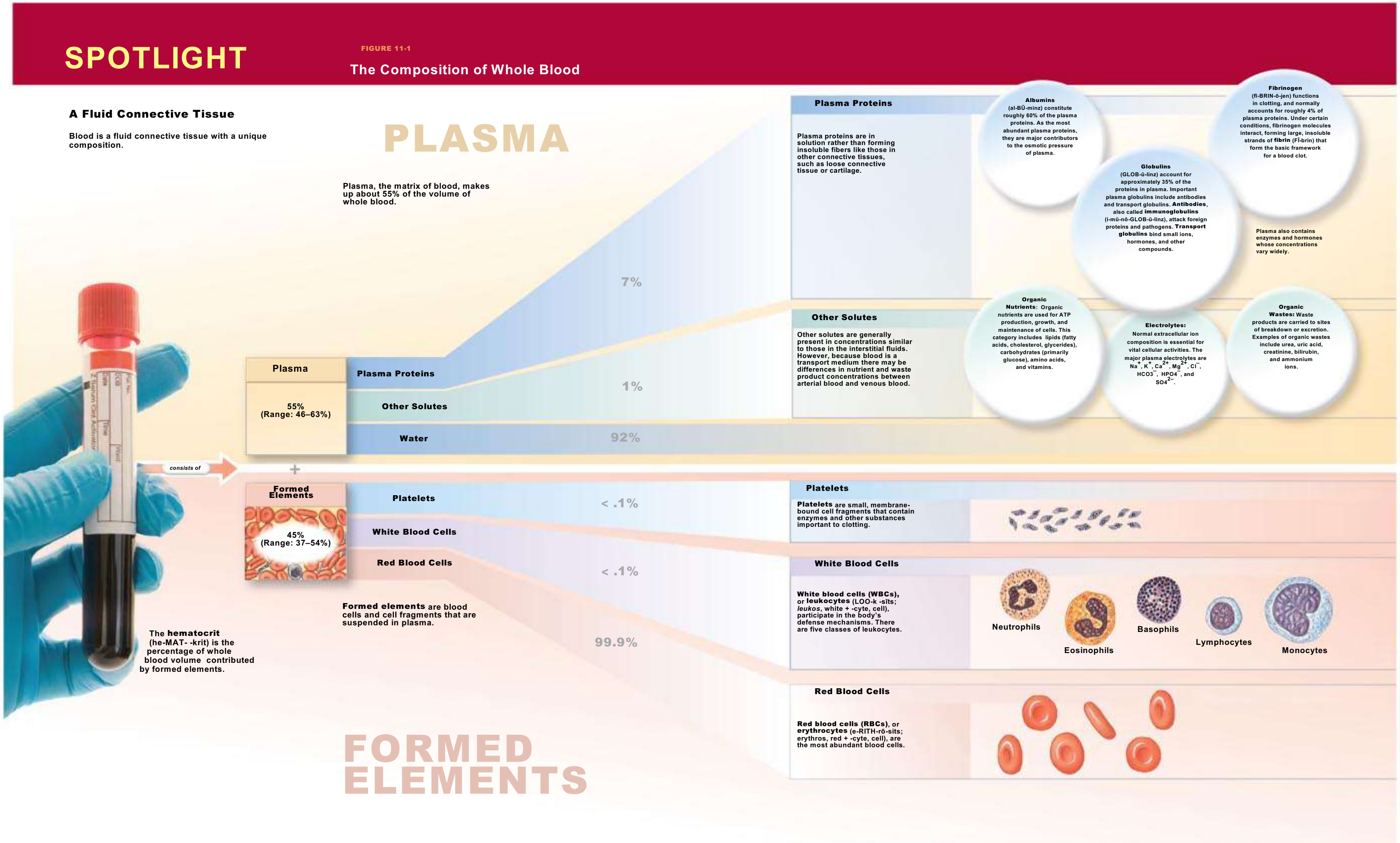


Figure 11-1a The Composition of Whole Blood

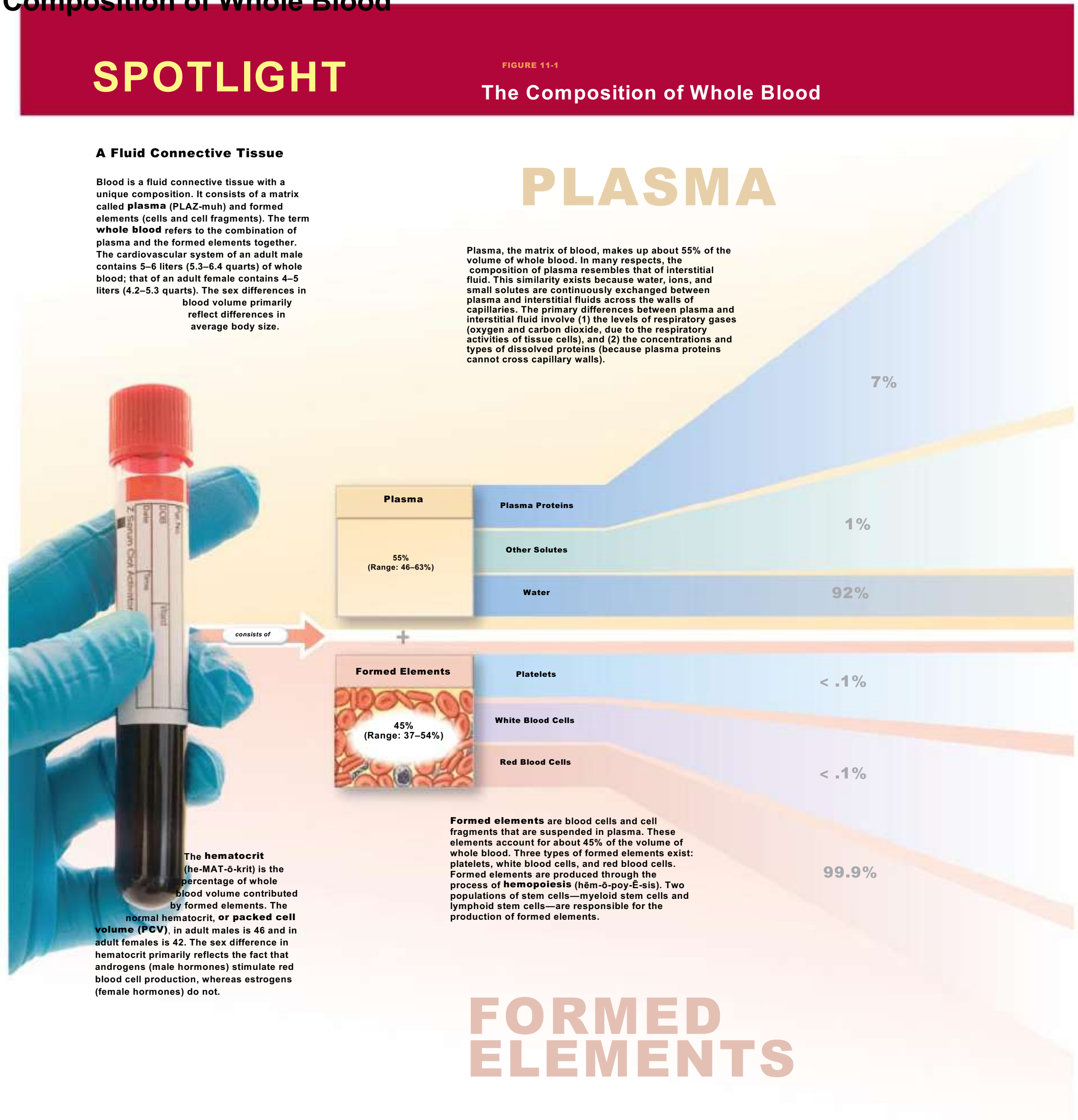


Figure 11-1-1 The Composition of Whole Blood

A Fluid Connective Tissue

Blood is a fluid connective tissue with a unique composition. It consists of a matrix called **plasma** (PLAZ-muh) and formed elements (cells and cell fragments). The term **whole blood** refers to the combination of plasma and the formed elements together. The cardiovascular system of an adult male contains 5–6 liters (5.3–6.4 quarts) of whole blood; that of an adult female contains 4–5 liters (4.2–5.3 quarts). The sex differences in blood volume primarily reflect differences in average body size.

PLASMA

Plasma, the matrix of blood, makes up about 55% of the volume of whole blood. In many respects, the composition of plasma resembles that of interstitial fluid. This similarity exists because water, ions, and small solutes are continuously exchanged between plasma and interstitial fluids across the walls of capillaries. The primary differences between plasma and interstitial fluid involve (1) the levels of respiratory gases (oxygen and carbon dioxide, due to the respiratory activities of tissue cells), and (2) the concentrations and types of dissolved proteins (because plasma proteins cannot cross capillary walls).

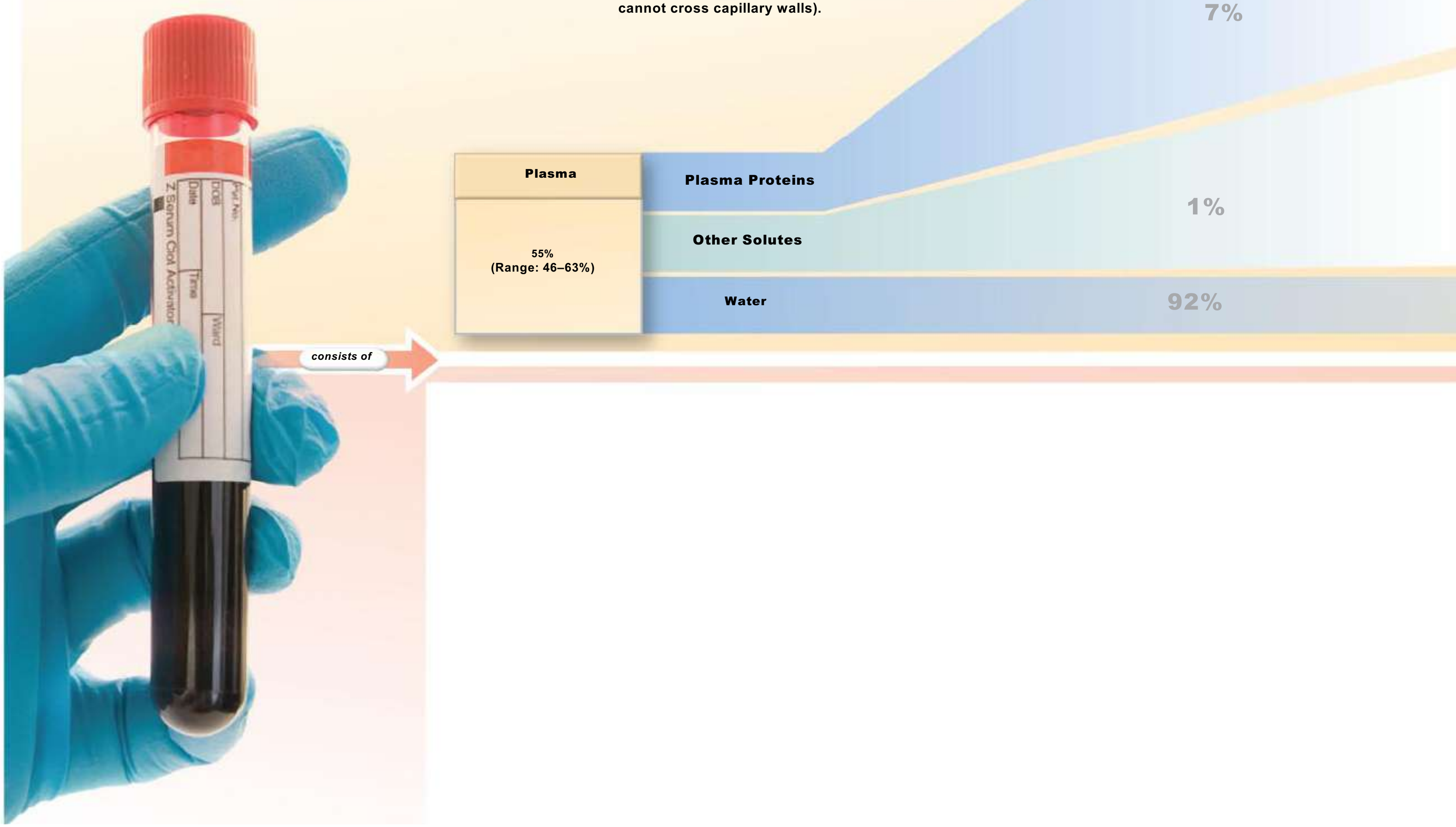


Figure 11-1-2 The Composition of Whole Blood

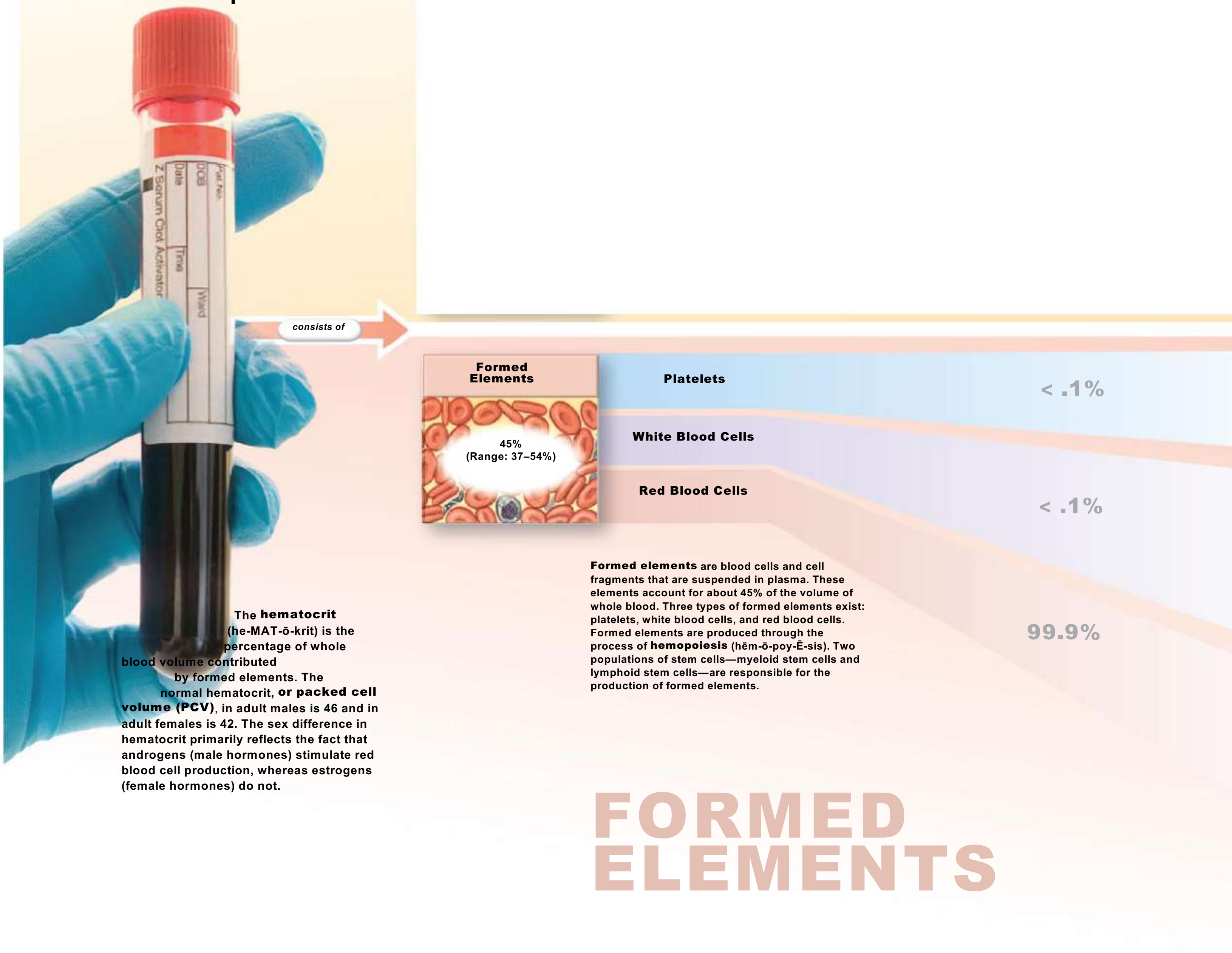


Figure 11-1 The Composition of Whole Blood (3–4)

Plasma Proteins

Plasma proteins are in solution rather than forming insoluble fibers like those in other connective tissues, such as loose connective tissue or cartilage. On average, each 100 mL of plasma contains 7.6 g of protein, almost five times the concentration in interstitial fluid.The large size and globular shapes of most blood proteins prevent them from crossing capillary walls, so they remain trapped within the bloodstream. The liver synthesizes and releases more than 90% of the plasma proteins, including all albumins and fibrinogen, most globulins, and various prohormones.

Albumins (al-BŪ-minz) constitute roughly 60% of the plasma proteins. As the most abundant plasma proteins, they are major contributors to the osmotic pressure of plasma.

Globulins (GLOB-ū-linz) account for approximately 35% of the proteins in plasma. Important plasma globulins include antibodies and transport globulins. **Antibodies**, also called **immunoglobulins** (i-mū-nō-GLOB-ū-linz), attack foreign proteins and pathogens. **Transport globulins** bind small ions, hormones, and other compounds.

Fibrinogen (fī-BRIN-ō-jen) functions in clotting, and normally accounts for roughly 4% of plasma proteins. Under certain conditions, fibrinogen molecules interact, forming large, insoluble strands of **fibrin** (FĪ-brin) that form the basic framework for a blood clot.

Plasma also contains enzymes and hormones whose concentrations vary widely.

Other Solutes

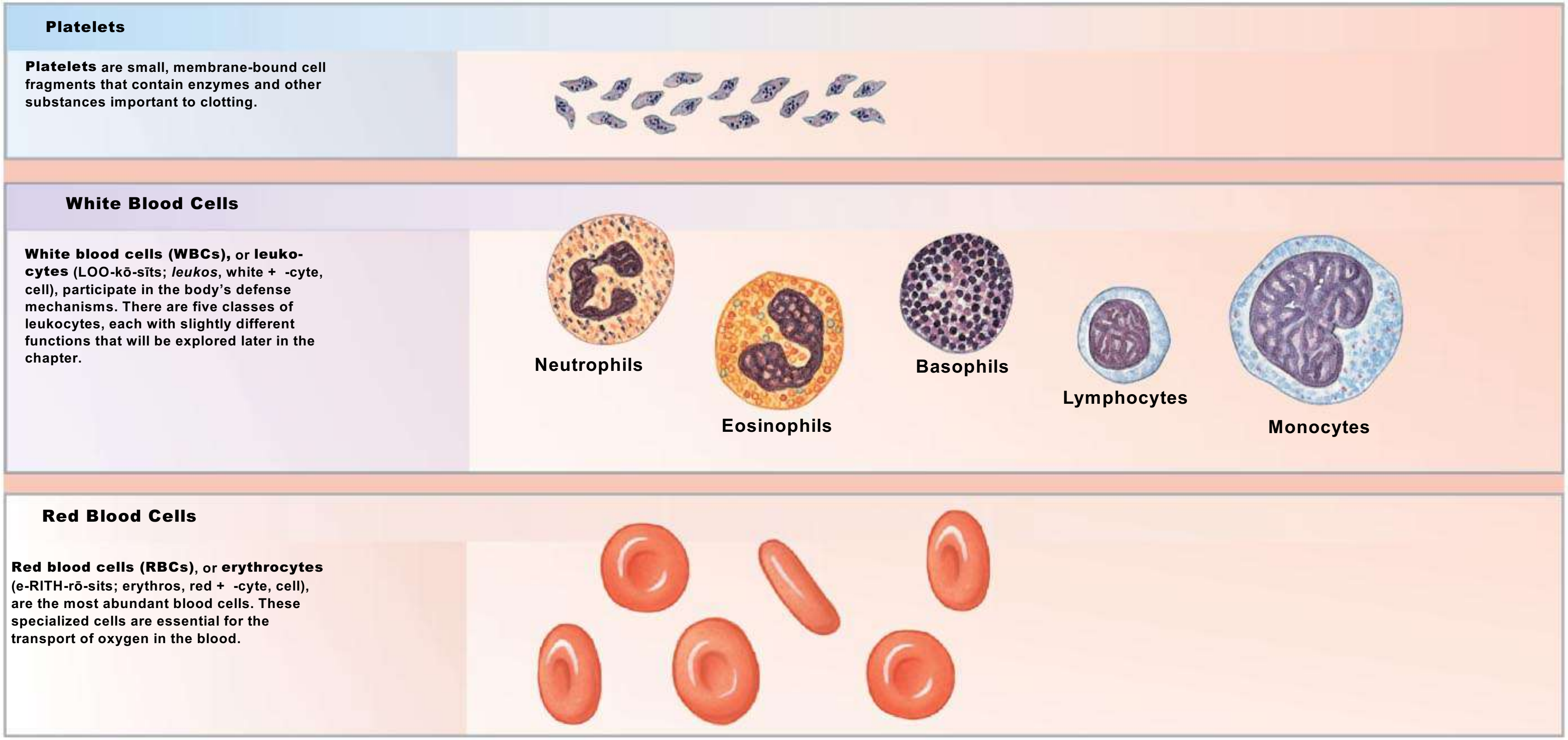
Other solutes are generally present in concentrations similar to those in the interstitial fluids. However, because blood is a transport medium there may be differences in nutrient and waste product concentrations between arterial blood and venous blood.

Organic Nutrients: Organic nutrients are used for ATP production, growth, and maintenance of cells. This category includes lipids (fatty acids, cholesterol, glycerides), carbohydrates (primarily glucose), amino acids, and vitamins.

Electrolytes: Normal extracellular ion composition is essential for vital cellular activities. The major plasma electrolytes are Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^-, HPO_4^-, and SO_4^{2-}.

Organic Wastes: Waste products are carried to sites of breakdown or excretion. Examples of organic wastes include urea, uric acid, creatinine, bilirubin, and ammonium ions.

Figure 11-1 The Composition of Whole Blood (5–7)



Checkpoint (11-2)

4. List the three major types of plasma proteins.
5. What would be the effects of a decrease in the amount of plasma proteins?

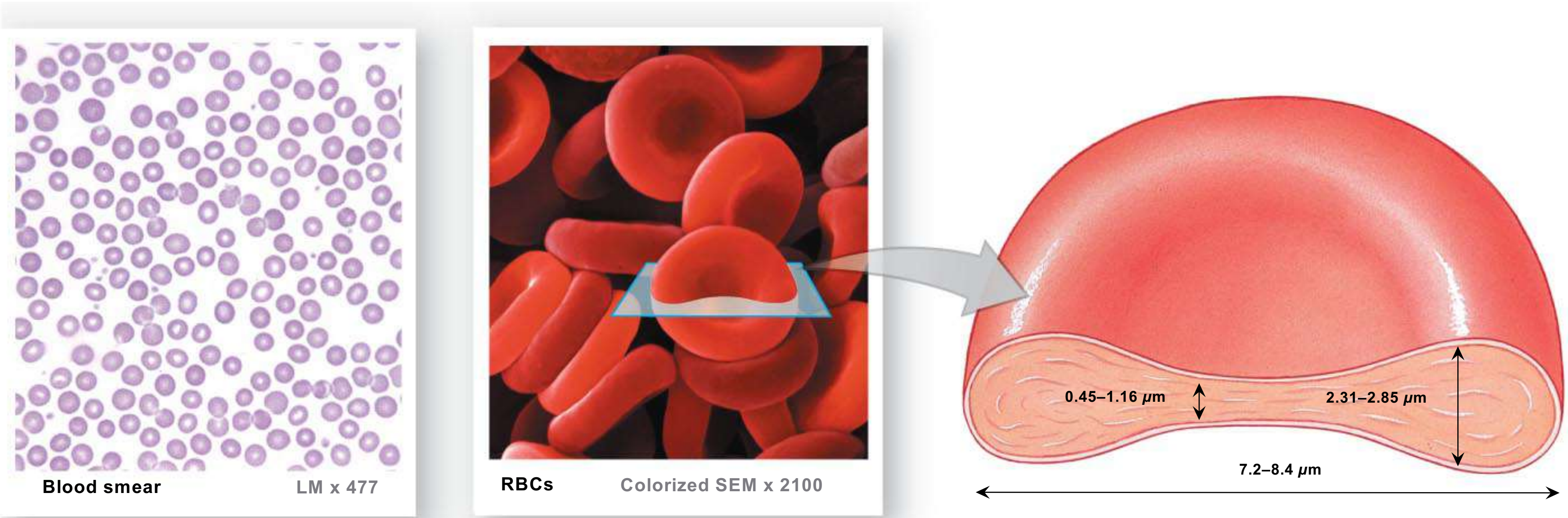
Erythrocytes or Red Blood Cells (11-3)

- RBCs
  - Make up 99.9 percent of formed elements
  - Measured in red blood cell count, cells/μL
    - Men have 5.4 million/μL
    - Women have 4.8 million/μL
  - Measured as a percentage of whole blood
    - Hematocrit in men is 46 percent
    - In women, it's 42 percent
  - Contain pigment molecule hemoglobin
    - Transports oxygen and carbon dioxide

Structure of RBCs (11-3)

- Unique biconcave shape provides advantages
  - Increased surface area increases rate of diffusion
  - Increased flexibility to squeeze through narrow capillaries
- During RBC formation organelles are lost
  - Cannot go through cell division
  - Can only rely on glucose from plasma for energy

Figure 11-2 The Anatomy of Red Blood Cells.



a When viewed in a standard blood smear, RBCs appear as two-dimensional objects, because they are flattened against the surface of the slide.

b The three-dimensional shape of RBCs.

c A sectional view of a mature RBC, showing the normal ranges for its dimensions.

Hemoglobin Structure (11-3)

- **Hb** structure
  - 95 percent of all RBC intracellular proteins
  - Transports oxygen and carbon dioxide
  - Composed of two pairs of globular proteins, called subunits
  - Each subunit contains **heme**, with an iron atom
  - Oxygen binds to heme, carbon dioxide binds to the globular subunits

Hemoglobin Function (11-3)

- O_2–heme bond is fairly weak
- High plasma O_2
  - Causes hemoglobin to gain O_2 until saturated
  - Occurs as blood circulates through lung capillaries
- Low plasma O_2 and high CO_2
  - Causes hemoglobin to release O_2
  - Occurs as blood circulates through systemic capillaries

Anemia (11-3)

- A reduction in oxygen-carrying capacity
- Caused by:
  - Low hematocrit
  - Low hemoglobin content in RBCs
- Symptoms include:
  - Muscle fatigue and weakness
  - Lack of energy in general

RBC Life Span and Circulation (11-3)

- RBCs are exposed to stresses of friction and wear and tear
  - Move through small capillaries
  - Bounce against walls of blood vessels
- Life span is about 120 days
  - About 1 percent of all RBCs are replaced each day
  - About 3 million new RBCs enter circulation per second

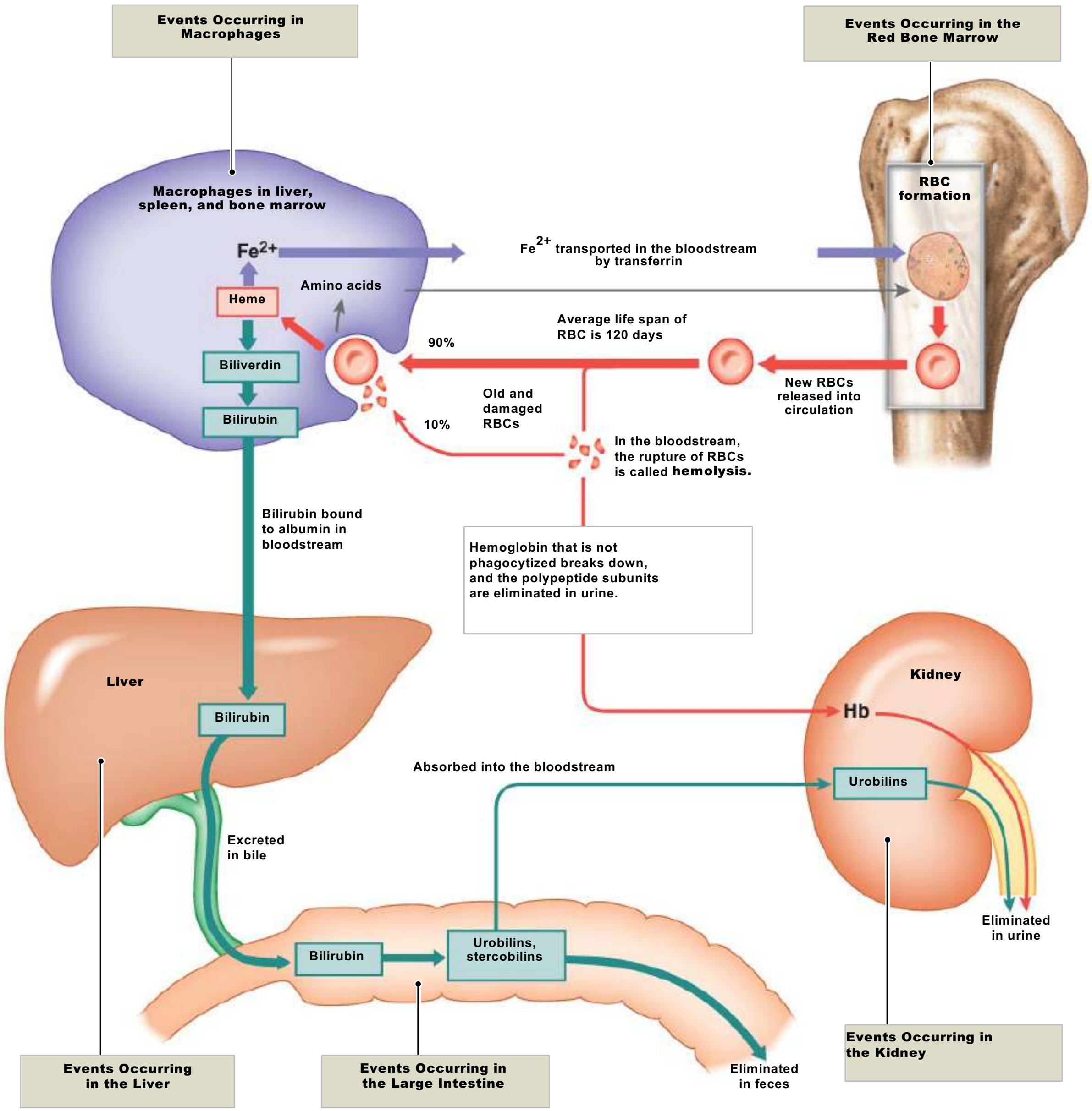
Hemoglobin Recycling (11-3)

- If RBCs **hemolyze** in bloodstream, Hb breaks down in blood
  - Kidneys filter out Hb
    - If a lot of RBCs rupture at once it causes **hemoglobinuria**, indicated by reddish-brown urine
- Most RBCs are phagocytized in liver, spleen, and bone marrow
  - Hb components are recycled

Three Steps of Hemoglobin Recycling (11-3)

1. Globular proteins are broken into amino acids
2. Heme is stripped of iron, converted to **biliverdin**
    - Biliverdin is converted to **bilirubin**, orange-yellow
    - Liver absorbs bilirubin, it becomes part of bile
    - If not put into bile, tissues become yellow, **jaundiced**
3. Iron can be stored or released into blood to bind with **transferrin**

Figure 11-4 Recycling of Hemoglobin.



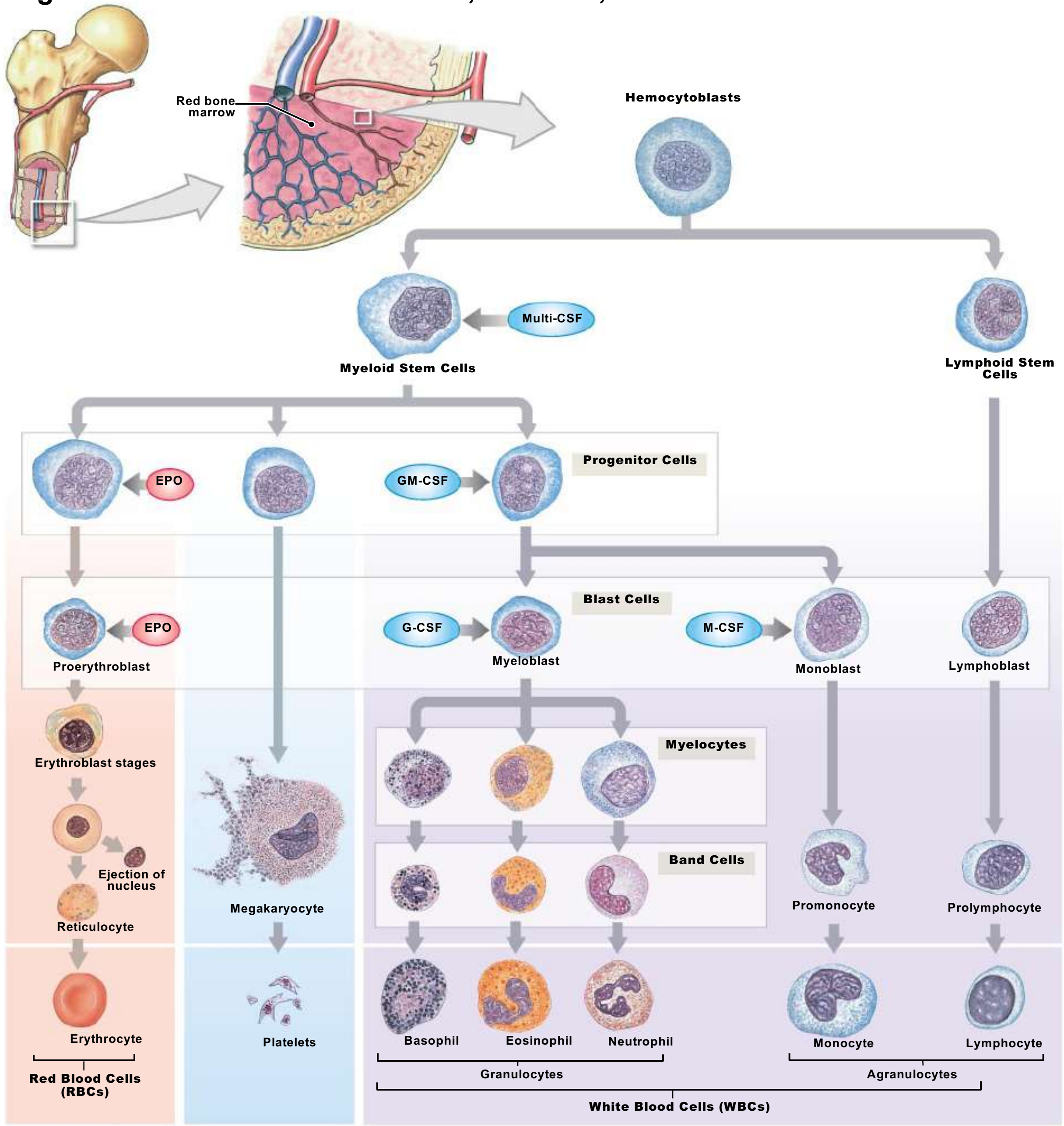
Gender and Iron Reserves (11-3)

- Men have about 3.5 g of ionic Fe^{2+}, 2.5 g of that is in Hb, providing a reserve of 1 g
- Women have 2.4 g of Fe^{2+} and 1.9 g in Hb, providing a reserve of only 0.5 g
- Women often require dietary supplements
- If low, iron deficiency anemia may appear

Stages of Erythropoiesis (11-3)

- Also called RBC formation
  - Embryonic cells differentiate into multipotent stem cells, called **hemocytoblasts**
  - **Erythropoiesis** occurs in red bone marrow, or **myeloid tissue**
  - Hemocytoblasts produce **myeloid stem cells**
  - **Erythroblasts** are immature and are synthesizing Hb
  - When nucleus is shed they becomes **reticulocytes**
  - Reticulocytes enter bloodstream to mature into RBCs

Figure 11-5 The Origins and Differentiation of RBCs, Platelets, and WBCs.



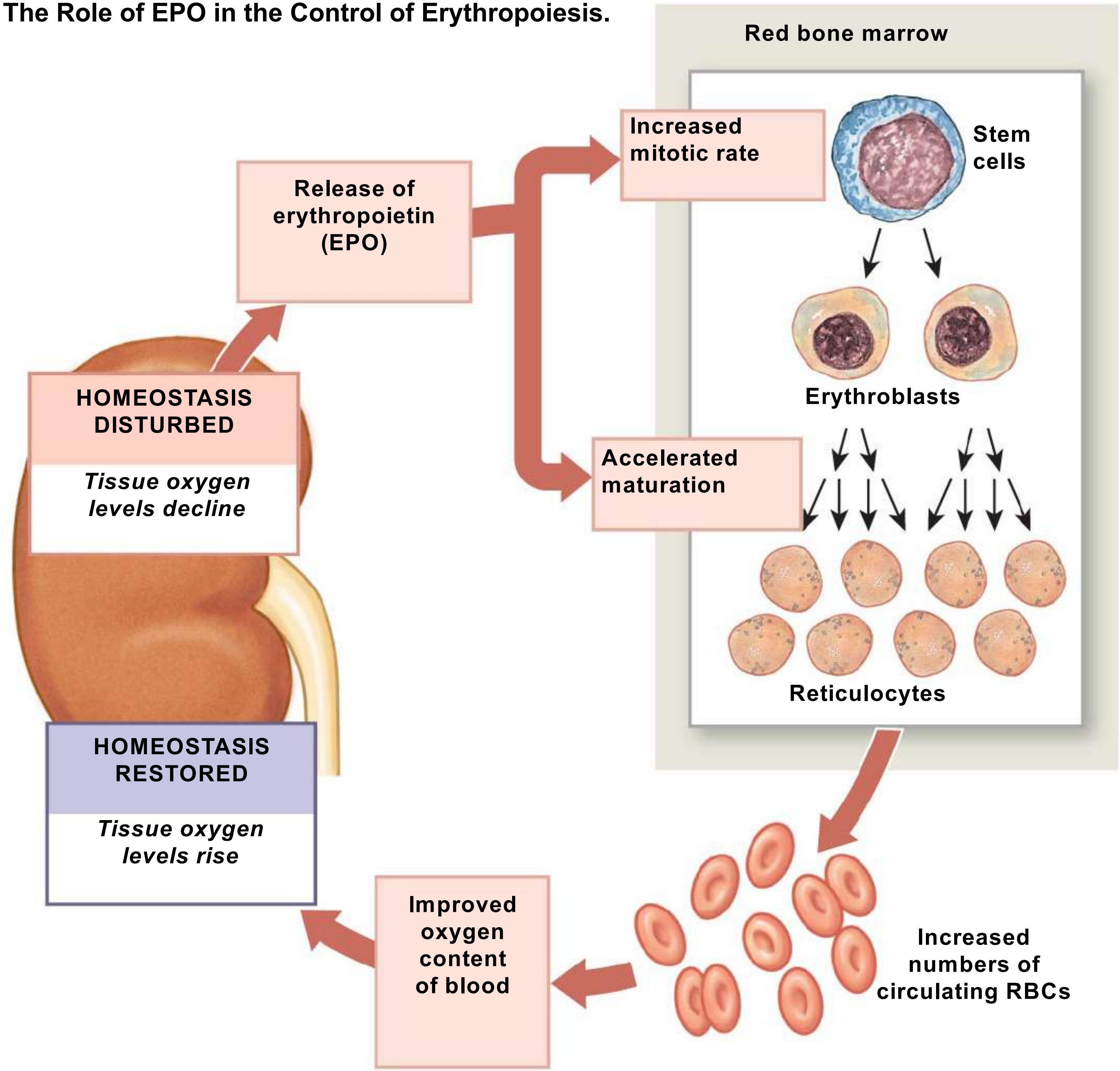
Regulation of Erythropoiesis (11-3)

- Requires amino acids, iron, and B vitamins
- Stimulated by low tissue oxygen, called **hypoxia**
- Kidney hypoxia triggers release of **erythropoietin**
  - When blood flow to kidney decreases
  - When anemia occurs
  - When oxygen content of air declines
  - When damage to respiratory membrane occurs

Erythropoietin (11-3)

- EPO
- Target tissue is myeloid stem cell tissue
  - Stimulates increase in cell division
  - Speeds up rate of maturation of RBCs
  - Essential for patients recovering from blood loss
  - EPO infusions can help cancer patients recover from RBC loss due to chemotherapy

Figure 11-6 The Role of EPO in the Control of Erythropoiesis.



Checkpoint (11-3)

6. Describe hemoglobin.
7. What effect does dehydration have on an individual's hematocrit?
8. In what way would a disease that causes liver damage affect the level of bilirubin in the blood?
9. What effect does a reduction in oxygen supply to the kidneys have on levels of erythropoietin in the blood?

ABO Blood Types and Rh System (11-4)

- Based on antigen–antibody responses
  - *Antigens*, or *agglutinogens*, are substances that can trigger an *immune response*
  - Your surface antigens are considered normal, not foreign, and will not trigger an immune response
  - Presence or absence of antigens on membrane of RBC determines **blood type**
    - Three major antigens are **A, B,** and **Rh** (or **D**)

Blood Types (11-4)

- Type A blood has antigen A only
- Type B blood has antigen B only
- Type AB blood had both A and B
- Type O blood has neither A nor B
- **Rh positive** notation indicates the presence of the Rh antigen; **Rh negative**, the absence of it

Table 11-1 The Distribution of Blood Types in Selected Populations

Table 11-1 The Distribution of Blood Types in Selected Populations

Population	Percentage with Each Blood Type				
	O	A	B	AB	Rh^+
U.S. (AVERAGE)	46	40	10	4	85
African American	49	27	20	4	95
Caucasian	45	40	11	4	85
Chinese American	42	27	25	6	100
Filipino American	44	22	29	6	100
Hawaiian	46	46	5	3	100
Japanese American	31	39	21	10	100
Korean American	32	28	30	10	100
NATIVE NORTH AMERICAN	79	16	4	< 1	100
NATIVE SOUTH AMERICAN	100	0	0	0	100
AUSTRALIAN ABORIGINE	44	56	0	0	100

Antibodies (11-4)

- Also called *agglutinins*
- Found in plasma, will not attack your own antigens on your RBCs
- Will attack foreign antigens of different blood type
  - Type A blood contains anti-B antibodies
  - Type B blood contains anti-A antibodies
  - Type AB blood contains neither antibodies
  - Type O blood contains both antibodies

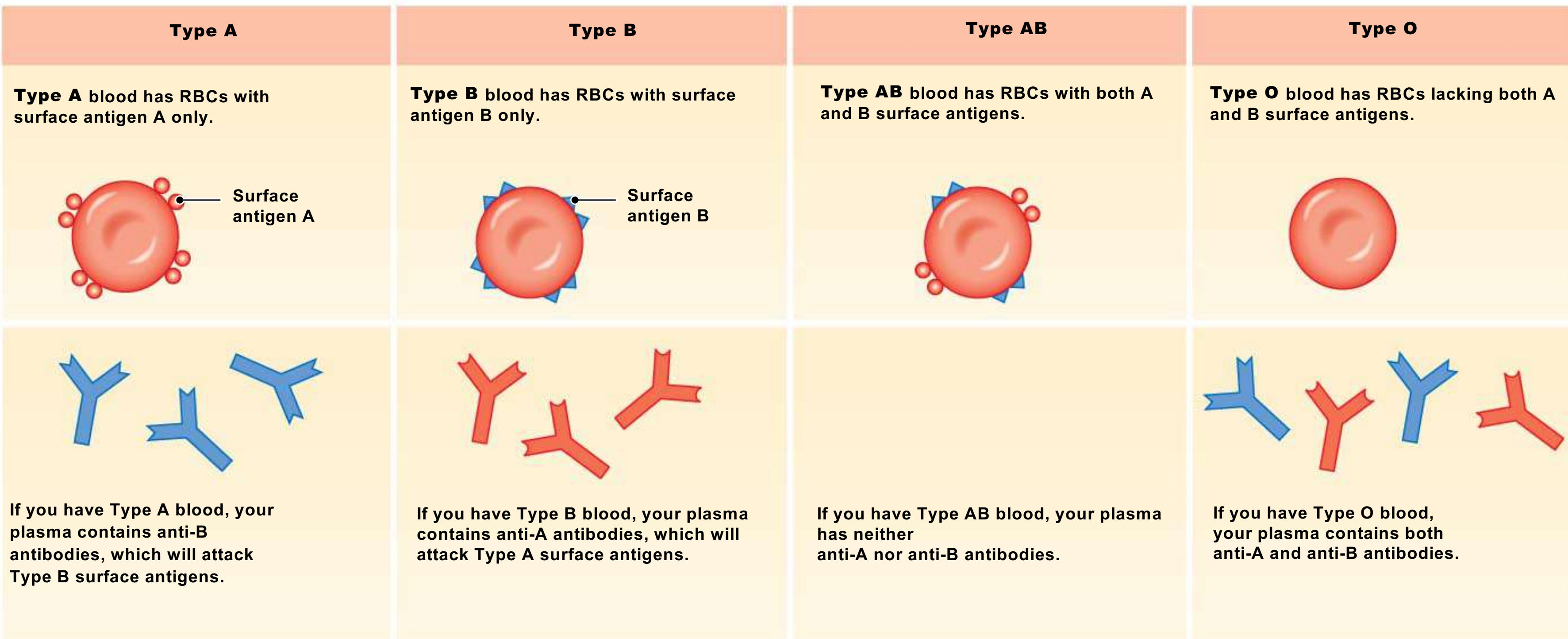
Cross-Reactions in Transfusions (11-4)

- Occur when antibodies in recipient react with their specific antigen on donor's RBCs
- Cause **agglutination** or clumping of RBCs
- Referred to as cross-reactions or *transfusion reactions*
- Checking blood types before transfusions ensures **compatibility**

The Difference between ABO and Rh (11-4)

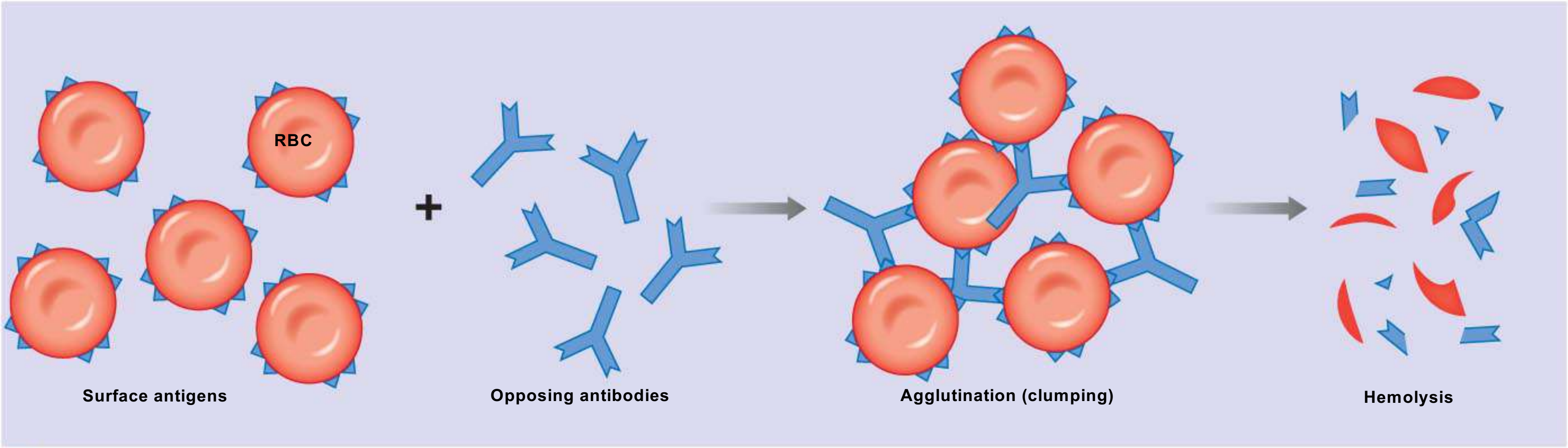
- Anti-A or anti-B antibodies
  - Spontaneously develop during first six months of life
  - No exposure to foreign antigens needed
- Anti-Rh antibodies in Rh negative person
  - Do not develop unless individual is exposed to Rh positive blood
  - Exposure can occur accidentally, during a transfusion or during childbirth

Figure 11-7a Blood Types and Cross-Reactions.



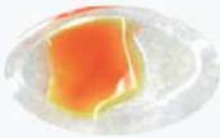
a Blood type depends on the presence of surface antigens (agglutinogens) on RBC surfaces. The plasma contains antibodies (agglutinins) that will react with foreign surface antigens.

Figure 11-7b Blood Types and Cross-Reactions.



b In a cross-reaction, antibodies react with their target antigens causing agglutination and hemolysis of the affected RBCs.

Figure 11-8 Blood Type Testing.

Anti-A	Anti-B	Anti-Rh	Blood type
			A^+
			B^+
			AB^+
			O^-

Checkpoint (11-4)

10. Which blood type(s) can be safely transfused into a person with Type AB blood?
11. Why can't a person with Type A blood safely receive blood from a person with Type B blood?

Leukocytes or White Blood Cells (11-5)

- WBCs
  - Larger than RBCs, involved in immune responses
  - Contain nucleus and other organelles and lack hemoglobin
  - **Granulocytes**
    - **Neutrophils**, **eosinophils**, **basophils**
  - **Agranulocytes**
    - **Lymphocytes** and **monocytes**

WBC Circulation and Movement (11-5)

- Four characteristics of WBCs

1. All are capable of amoeboid movement
2. All can migrate outside of bloodstream through **diapedesis**
3. All are attracted to specific chemical stimuli, referred to as **positive chemotaxis**, guiding them to pathogens
4. Neutrophils, eosinophils, and monocytes are phagocytes

Types of WBCs (11-5)

- **Neutrophils, eosinophils, basophils**, and **monocytes**
  - Respond to any threat
  - Are part of the nonspecific immune response
- **Lymphocytes**
  - Respond to specific, individual pathogens
  - Are responsible for specific immune response

Neutrophils (11-5)

- Make up 50–70 percent of circulating WBCs
- Have a dense, contorted multilobular nucleus
- Usually first WBC to arrive at injury
- Phagocytic, attacking and digesting bacteria
- Numbers increase during acute bacterial infections

Eosinophils (11-5)

- Make up 2–4 percent of circulating WBCs
- Similar in size to neutrophils
- Have deep red granules and a two-lobed nucleus
- Are phagocytic, but also attack through exocytosis of toxic compounds
- Numbers increase during parasitic infection or allergic reactions

Basophils (11-5)

- Somewhat smaller than neutrophils and eosinophils
- Rare, less than 1 percent of circulating WBCs
- Granules contain:
  - An anticoagulant, *heparin*
  - Inflammatory compound, *histamine*

Monocytes (11-5)

- About twice the size of a RBC with a large, kidney bean–shaped nucleus
- Usually 2–8 percent of circulating WBCs
- Migrate into tissues and become macrophages
- Aggressive phagocytes

Lymphocytes (11-5)

- Slightly larger than typical RBC with nucleus taking up most of cell
- About 20–40 percent of circulating WBCs
- Large numbers are migrating in and out of tissues and lymphatics
- Some attack foreign cells, others secrete antibodies into circulation

The Differential WBC Count (11-5)

- Counting the numbers of the five unique WBCs of a stained blood smear, called a **differential count**
- Change in numbers or percentages is diagnostic
- **Leukopenia**
  - Is a reduction in total WBCs
- **Leukocytosis**
  - Is excessive numbers of WBCs
- **Leukemia**
  - Is an extremely high WBC count and is a cancer of blood-forming tissues

WBC Formation (11-5)

- Derived from hemocytoblasts
- Regulated by colony-stimulating factors, thymosins
  - Produce lymphoid stem cells
    - Differentiate into lymphocytes, called **lymphopoiesis**
    - Migrate from bone marrow to **lymphatic tissues**
  - Produce myeloid stem cells
    - Differentiate into all other formed elements

Checkpoint (11-5)

12. Identify the five types of white blood cells.
13. Which type of white blood cell would you expect to find in the greatest numbers in an infected cut?
14. Which type of cell would you find in elevated numbers in a person producing large amounts of circulating antibodies to combat a virus?
15. How do basophils respond during inflammation?

Table 11-2 A Review of the Formed Elements of the Blood (1 of 2)

Table 11-2 A Review of the Formed Elements of the Blood

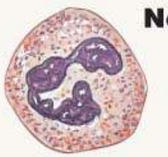
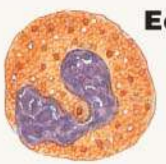
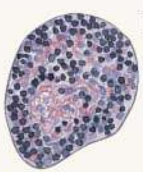
	Cell	Abundance (Average Per μL)	Functions	Remarks
	**RED BLOOD CELLS**	5.2 million (range: 4.4–6.0 million)	Transport oxygen from lungs to tissues, and carbon dioxide from tissues to lungs	Remain in bloodstream; 120-day life expectancy; amino acids and iron recycled; produced in red bone marrow
	WHITE BLOOD CELLS	7000 (range: 6000–9000)		
	**Neutrophils**	4150 (range: 1800–7300) Differential count: 50–70%	Phagocytic: Engulf pathogens or debris in tissues, release cytotoxic enzymes and chemicals	Move into tissues after several hours; survive minutes to days, depending on tissue activity; produced in red bone marrow
	**Eosinophils**	165 (range: 0–700) Differential count: 2–4%	Phagocytic: Engulf antibody-labeled materials, release cytotoxic enzymes, reduce inflammation; increase during allergic and parasitic situations	Move into tissues after several hours; survive minutes to days, depending on tissue activity; produced in red bone marrow
	**Basophils**	44 (range: 0–150) Differential count: <1%	Enter damaged tissues and release histamine and other chemicals that promote inflammation	Survival time unknown; assist mast cells of tissues in producing inflammation; produced in red bone marrow

Table 11-2 A Review of the Formed Elements of the Blood (2 of 2)

Table 11-2 A Review of the Formed Elements of the Blood *(Continued)*

	Cell	Abundance (Average Per µL)	Functions	Remarks
	**Monocytes**	456 (range: 200–950) Differential count: 2–8%	Enter tissues to become macrophages; engulf pathogens or debris	Move into tissues after 1–2 days; survive months or longer; primarily produced in bone marrow
	**Lymphocytes**	2185 (range: 1500–4000) Differential count: 20–40%	Cells of lymphatic system, providing defense against specific pathogens or toxins	Survive months to decades; circulate from blood to tissues and back; produced in red bone marrow and lymphatic tissues
	**PLATELETS**	350,000 (range: 150,000–500,000)	Hemostasis: Clump together and stick to vessel wall (platelet phase); activate intrinsic pathway of coagulation phase	Remain in circulation or in vascular organs (such as the spleen); remain intact for 7–12 days; produced by megakaryocytes in red bone marrow

Platelets (11-6)

- Cell fragments involved in prevention of blood loss
  - Hemocytoblasts differentiate into **megakaryocytes**
- Contain granules of chemicals
  - Initiate clotting process and aid in closing tears in blood vessels
- Normal count is 150,000–500,000/*µL*
- Low count is called thrombocytopenia

Checkpoint (11-6)

16. Explain the difference between platelets and thrombocytes.
17. List the primary functions of platelets.

Three Phases of Hemostasis (11-7)

- Halts bleeding and prevents blood loss
  1. **Vascular phase**
  2. **Platelet phase**
  3. **Coagulation phase**

The Vascular Phase (11-7)

- Blood vessels contain smooth muscle lined with **endothelium**
- Damage causes decrease in vessel diameter
  - Endothelial cells become sticky
  - A vascular spasm of smooth muscle occurs

The Platelet Phase (11-7)

- Platelets attach to sticky endothelium and exposed collagen
- More platelets arrive and stick to each other forming a platelet plug
- May be enough to close a small break

The Coagulation Phase (11-7)

- Also called *blood clotting*
  - A chemical cascade of reactions that leads to fibrinogen being converted to fibrin
  - Fibrin mesh grows, trapping cells and more platelets forming a **blood clot**

The Clotting Process (11-7)

- Requires **clotting factors**
  - Calcium ions, vitamin K and 11 different plasma proteins
  - Proteins are converted from inactive proenzymes to active enzymes involved in reactions
- Cascade event
  - Step-by-step
  - Product of first reaction is enzyme that activates second reaction, etc.

The Extrinsic Pathway of Blood Clotting (11-7)

- Begins with damaged tissue releasing **tissue factor**
- Combines with calcium and other clotting proteins
- Leads to formation of enzyme that can activate Factor X

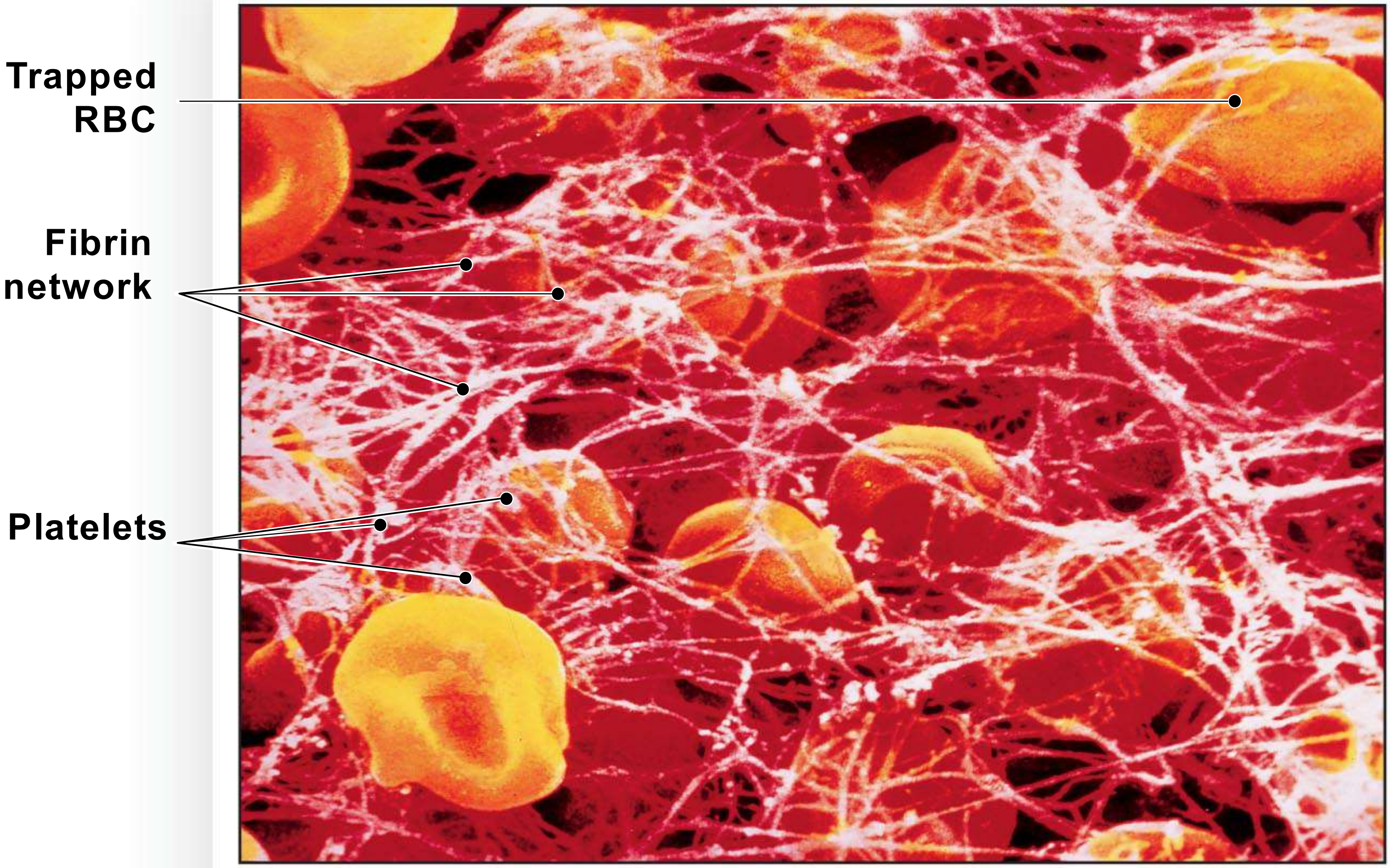
The Intrinsic Pathway of Blood Clotting (11-7)

- Begins with activation of proenzymes exposed to collagen fibers at injury site
- Proceeds with help from platelet factor released from aggregated platelets
- Several reactions occur, forming an enzyme that can activate Factor X

The Common Pathway of Blood Clotting (11-7)

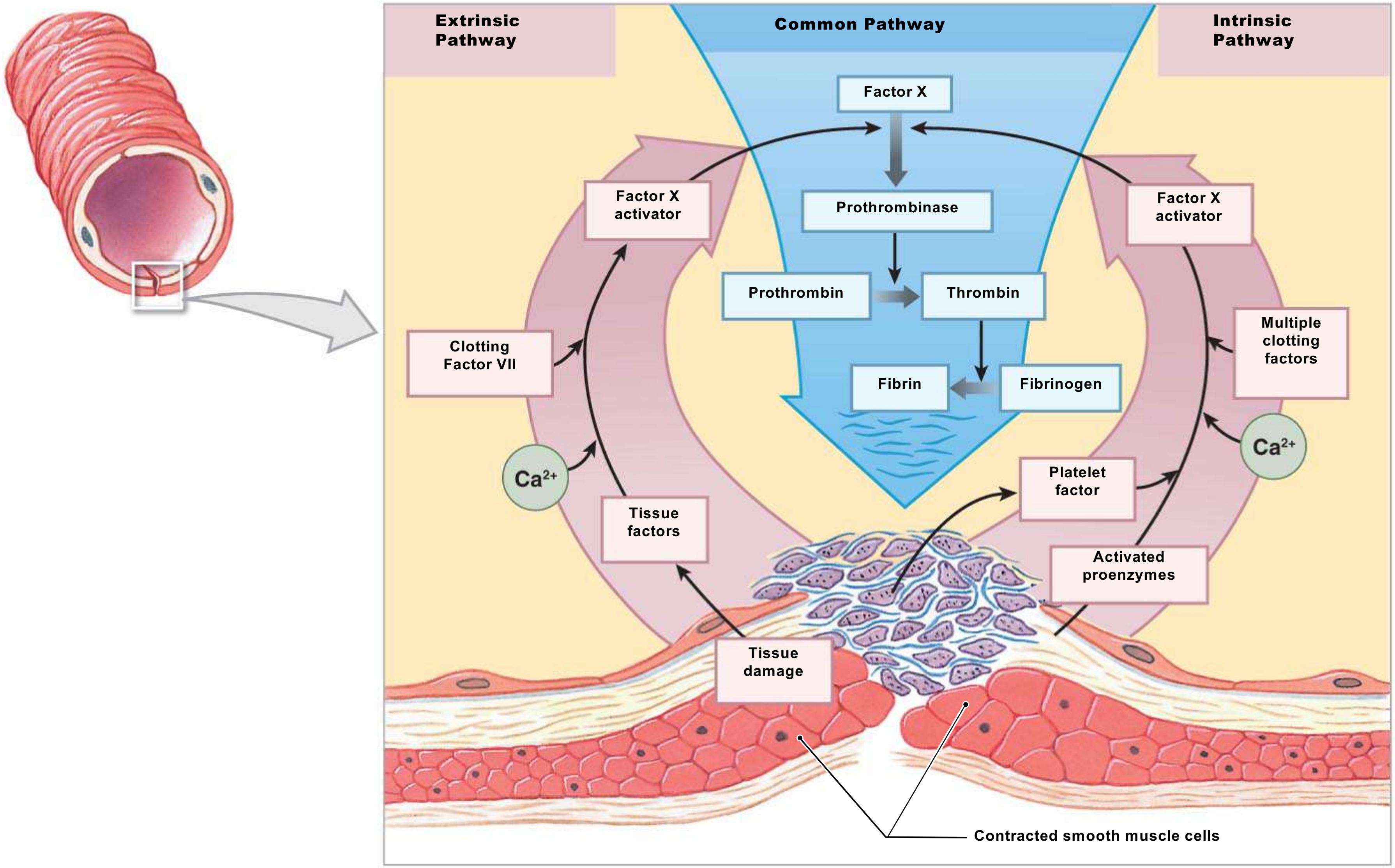
- Begins when enzymes from either extrinsic or intrinsic pathways activate Factor X
  - Forms enzyme prothrombinase
  - Which converts **prothrombin** into **thrombin**
  - Which converts fibrinogen into fibrin
  - And stimulates tissue factor and platelet factors
  - Positive feedback loop rapidly prevents blood loss

Figure 11-10 The Structure of a Blood Clot.



Blood clot containing trapped RBCs

Figure 11-11 Events in the Coagulation Phase of Hemostasis.



Clot Retraction and Removal (11-7)

- Fibrin network traps platelets and RBCs
  - Platelets contract, pulling tissue close together in **clot retraction**
- During repair of tissue, clot dissolves through **fibrinolysis**
  - **Plasminogen** is activated by thrombin and **tissue plasminogen activator** (**t-PA**)
  - Plasminogen produces **plasmin**, which digests clot

Checkpoint (11-7)

18. If a sample of red bone marrow has fewer than normal numbers of megakaryocytes, what body process would you expect to be impaired as a result?
19. Two alternate pathways of interacting clotting proteins lead to coagulation, or blood clotting. How is each pathway initiated?
20. What are the effects of a vitamin K deficiency on blood clotting (coagulation)?