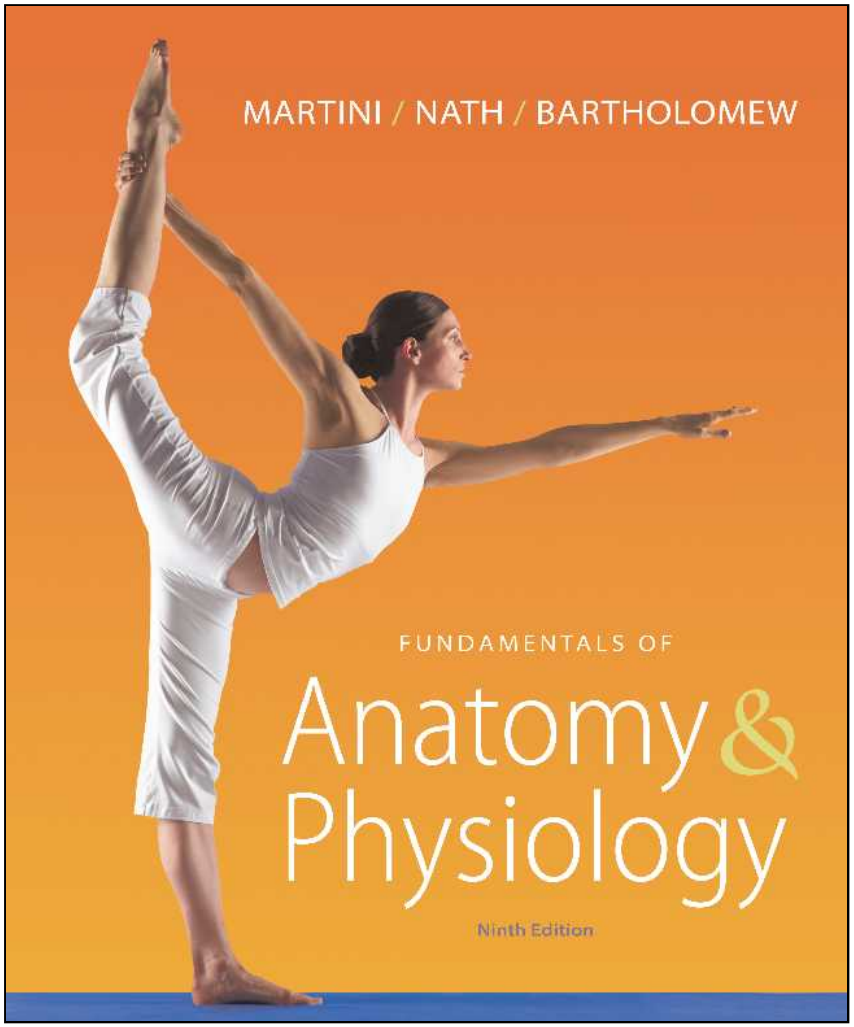


19

Blood

PowerPoint® Lecture Presentations prepared by Jason LaPres

Lone Star College—North Harris

An Introduction to Blood and the Cardiovascular System

- Learning Outcomes
  - **19-1** Describe the components and major functions of blood, identify blood collection sites, and list the physical characteristics of blood.
  - **19-2** Specify the composition and functions of plasma.
  - **19-3** List the characteristics and functions of red blood cells, describe the structure and functions of hemoglobin, describe how red blood cell components are recycled, and explain erythropoiesis.

An Introduction to Blood and the Cardiovascular System

- Learning Outcomes
  - **19-4** Explain the importance of blood typing, and the basis for ABO and Rh incompatibilities.
  - **19-5** Categorize white blood cell types based on their structures and functions, and discuss the factors that regulate the production of each type.
  - **19-6** Describe the structure, function, and production of platelets.
  - **19-7** Discuss the mechanisms that control blood loss after an injury, and describe the reaction sequences responsible for blood clotting.

An Introduction to Blood and the Cardiovascular System

- The **Cardiovascular System** consists of:
  - A pump (the heart)
  - A conducting system (blood vessels)
  - A fluid medium (**blood**)
    - Is specialized fluid of connective tissue
    - Contains cells suspended in a fluid matrix

An Introduction to Blood and the Cardiovascular System

- Blood
  - Transports materials to and from cells
    - Oxygen and carbon dioxide
    - Nutrients
    - Hormones
    - Immune system components
    - Waste products

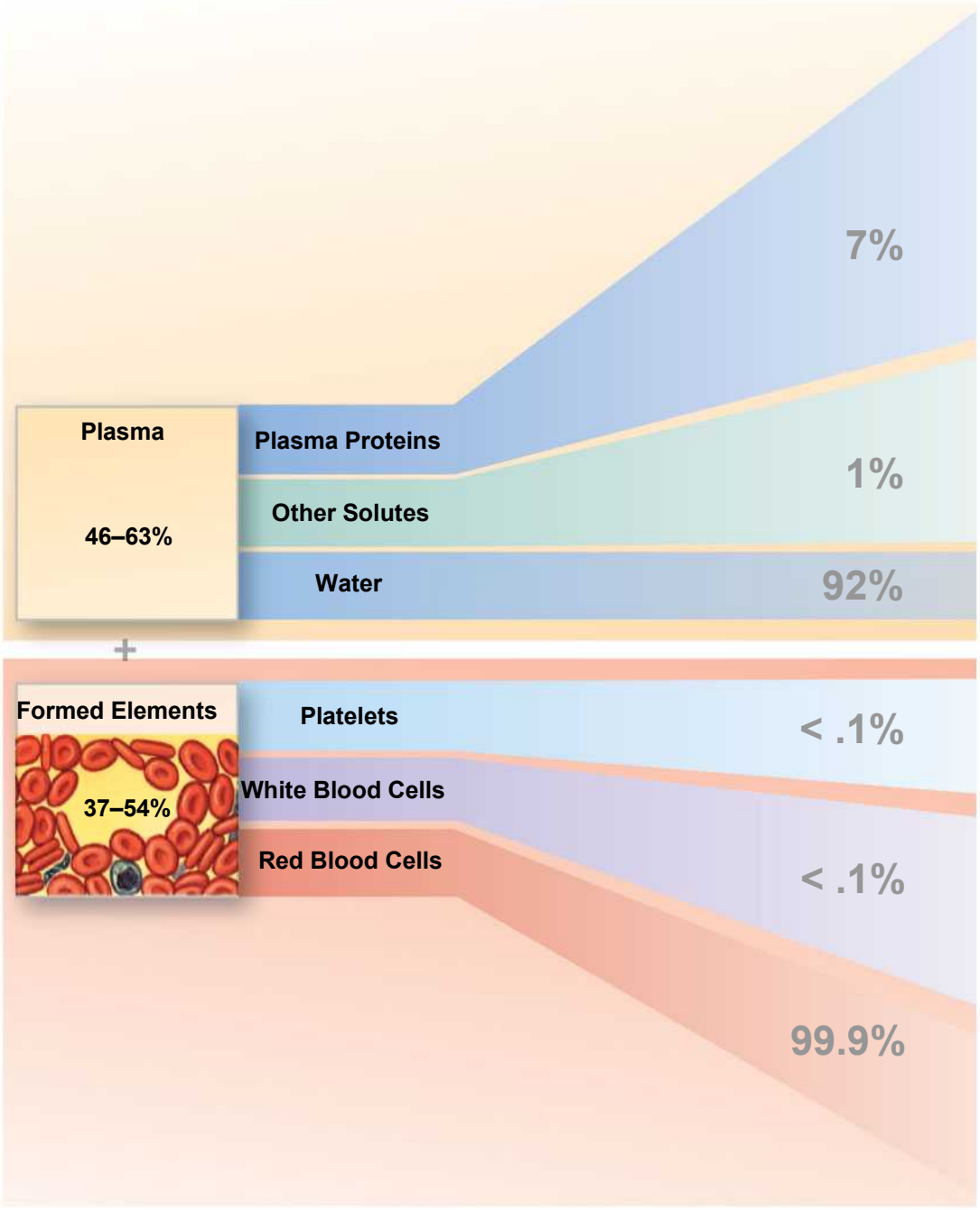
19-1 Physical Characteristics of Blood

- Important Functions of Blood
  - *Transportation of dissolved substances*
  - *Regulation of pH and ions*
  - *Restriction of fluid losses at injury sites*
  - *Defense against toxins and pathogens*
  - *Stabilization of body temperature*

19-1 Physical Characteristics of Blood

- Whole Blood
  - Plasma
    - Fluid consisting of:
      - Water
      - Dissolved plasma proteins
      - Other solutes
  - Formed elements
    - All cells and solids

Figure 19-1 The Composition of Whole Blood



19-1 Physical Characteristics of Blood

- Three Types of Formed Elements
  1. **Red blood cells (RBCs)** or **erythrocytes**
     - Transport oxygen
  1. **White blood cells (WBCs)** or **leukocytes**
     - Part of the immune system
  1. **Platelets**
     - Cell fragments involved in clotting

19-1 Physical Characteristics of Blood

- Hemopoiesis
  - Process of producing formed elements
  - By myeloid and lymphoid stem cells
- **Fractionation**
  - Process of separating whole blood for clinical analysis
    - Into plasma and formed elements

19-1 Physical Characteristics of Blood

- Three General Characteristics of Blood
  1. 38°C (100.4°F) is normal temperature
  2. High viscosity
  3. Slightly alkaline pH (7.35–7.45)

19-1 Physical Characteristics of Blood

- Characteristics of Blood
  - Blood volume (liters) = 7% of body weight (kilograms)
    - Adult male 5 to 6 liters
    - Adult female 4 to 5 liters

19-2 Plasma

- The Composition of Plasma
  - Makes up 50–60% of blood volume
  - More than 90% of plasma is water
  - Extracellular fluids
    - Interstitial fluid (IF) and plasma
    - Materials plasma and IF exchange across capillary walls
      - Water
      - Ions
      - Small solutes

19-2 Plasma

- Plasma Proteins
  - **Albumins** (60%)
  - **Globulins** (35%)
  - **Fibrinogen** (4%)

19-2 Plasma

- **Albumins** (60%)
  - Transport substances such as fatty acids, thyroid hormones, and steroid hormones
- **Globulins** (35%)
  - Antibodies, also called immunoglobulins
  - Transport globulins (small molecules): *hormone-binding proteins, metalloproteins, apolipoproteins (**lipoproteins**),* and *steroid-binding proteins*
- **Fibrinogen** (4%)
  - Molecules that form clots and produce long, insoluble strands of fibrin

19-2 Plasma

- **Serum**
  - Liquid part of a blood sample
    - In which dissolved **fibrinogen** has converted to solid fibrin

19-2 Plasma

- Other Plasma Proteins
  - 1% of plasma
    - Changing quantities of specialized plasma proteins
    - Peptide hormones normally present in circulating blood
      - Insulin, prolactin (PRL), and the glycoproteins thyroid-stimulating hormone (TSH), follicle-stimulating hormone (FSH), and luteinizing hormone (LH)

19-2 Plasma

- Origins of Plasma Proteins
  - More than 90% made in liver
  - Antibodies made by plasma cells
  - Peptide hormones made by endocrine organs

19-3 Red Blood Cells

- Red blood cells (RBCs)
  - Make up 99.9% of blood's formed elements
- *Hemoglobin*
  - The red pigment that gives whole blood its color
  - Binds and transports oxygen and carbon dioxide

19-3 Red Blood Cells

- Abundance of RBCs
  - *Red blood cell count* - the number of RBCs in 1 microliter of whole blood
    - Male: 4.5–6.3 million
    - Female: 4.2–5.5 million

19-3 Red Blood Cells

- Abundance of RBCs
  - Hematocrit - (packed cell volume, PCV) percentage of RBCs in centrifuged whole blood
    - Male: 40–54
    - Female: 37–47

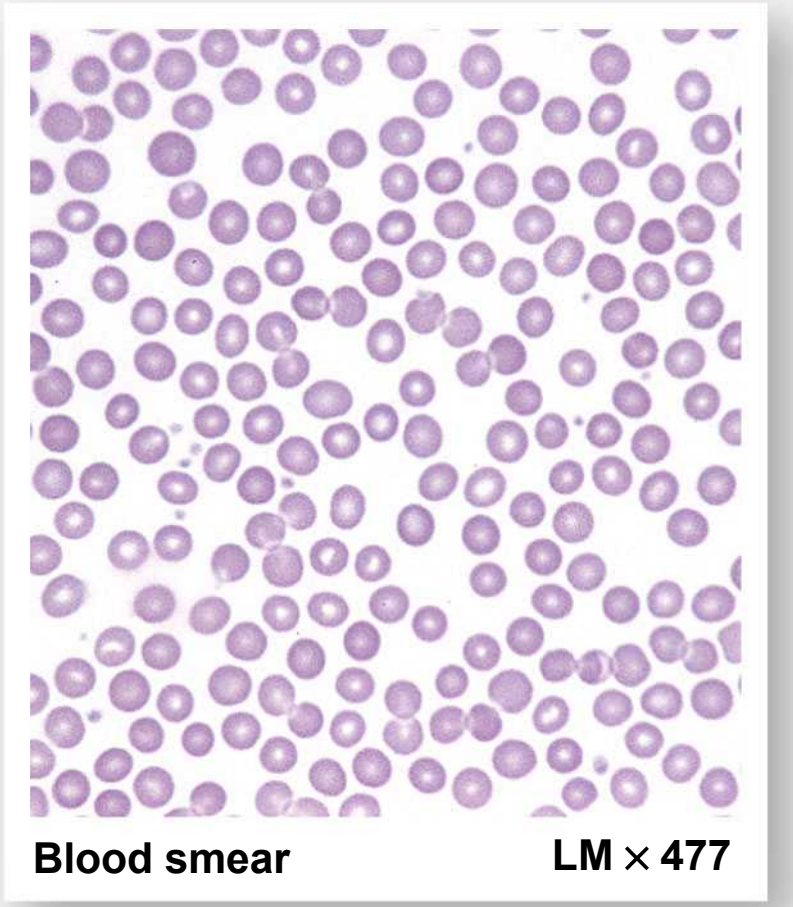
19-3 Red Blood Cells

- Structure of RBCs
  - Small and highly specialized discs
  - Thin in middle and thicker at edge

19-3 Red Blood Cells

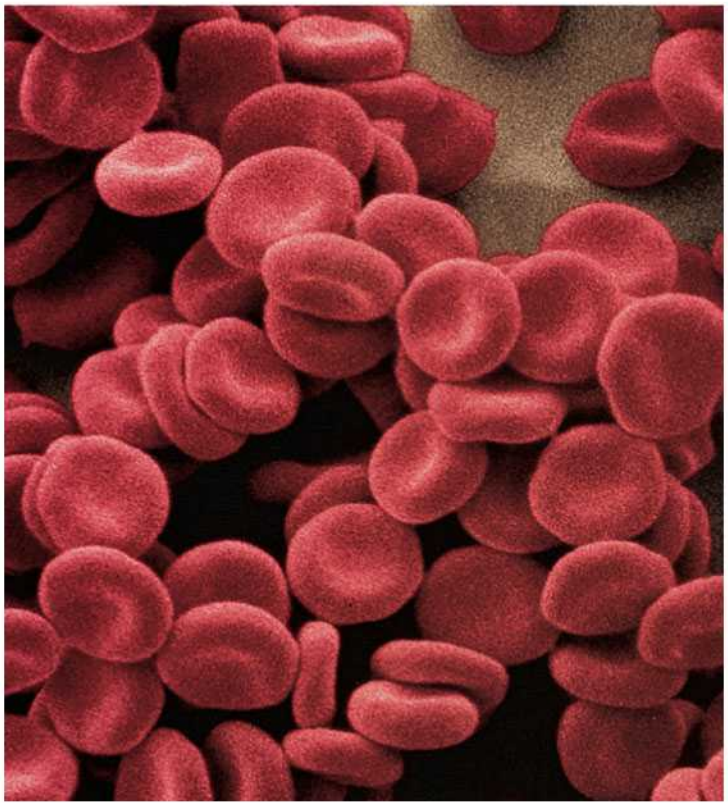
- Three Important Effects of RBC Shape on Function
  1. High surface-to-volume ratio
     - Quickly absorbs and releases oxygen
  1. Discs form stacks called *rouleaux*
     - Smooth the flow through narrow blood vessels
  1. Discs bend and flex entering small capillaries
     - 7.8-μm RBC passes through 4-μm capillary

Figure 19-2a 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.

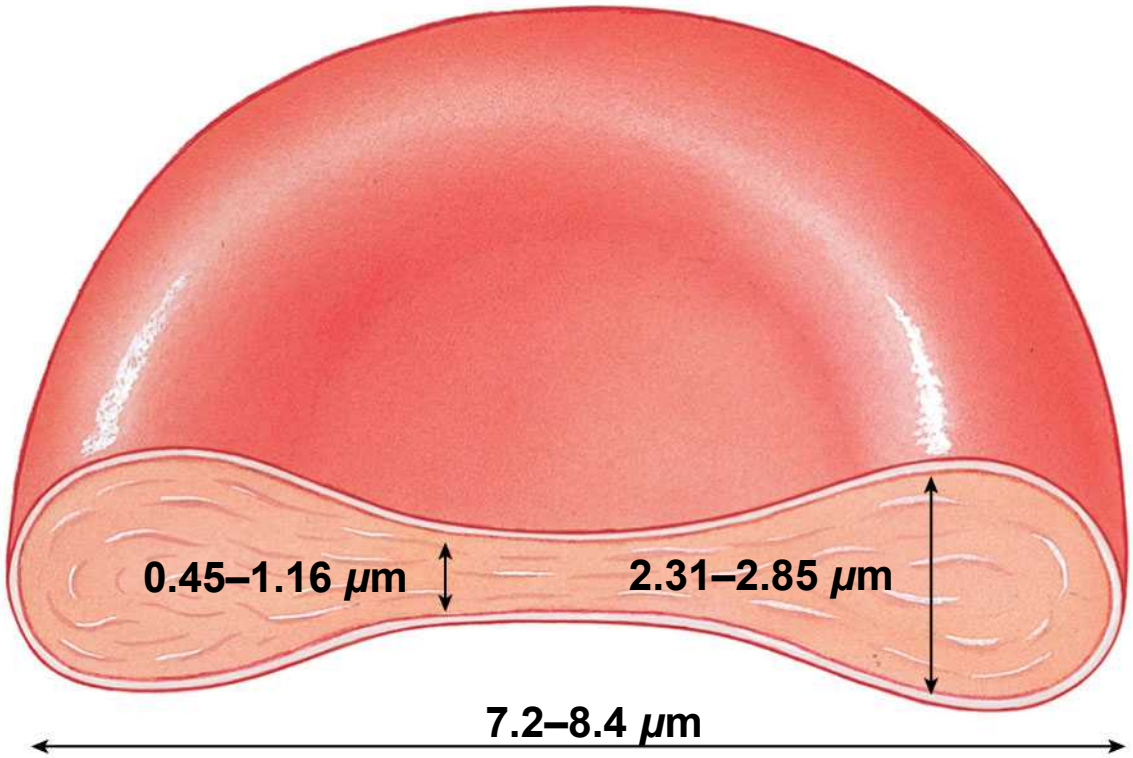
Figure 19-2b The Anatomy of Red Blood Cells



Red blood cells SEM × 1838

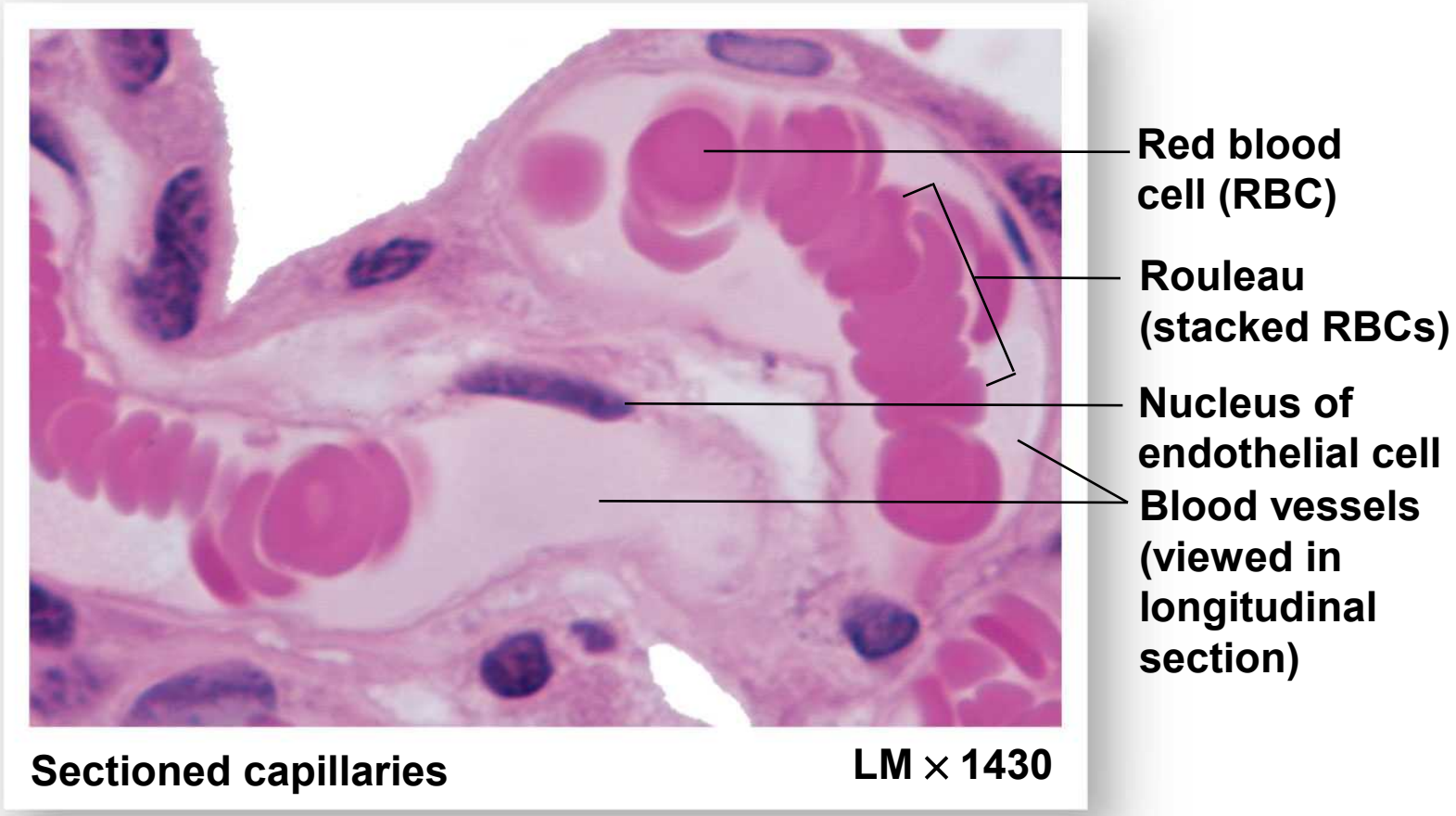
b The three-dimensional shape of RBCs

Figure 19-2c The Anatomy of Red Blood Cells



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

Figure 19-2d The Anatomy of Red Blood Cells



d When traveling through relatively narrow capillaries, RBCs may stack like dinner plates.

19-3 Red Blood Cells

- Life Span of RBCs
  - Lack nuclei, mitochondria, and ribosomes
    - Means no repair and anaerobic metabolism
    - Live about 120 days

19-3 Red Blood Cells

- **Hemoglobin (Hb)**
  - Protein molecule that transports respiratory gases
  - Normal hemoglobin (adult male)
    - 14–18 g/dL whole blood
  - Normal hemoglobin (adult female)
    - 12–16 g/dL whole blood

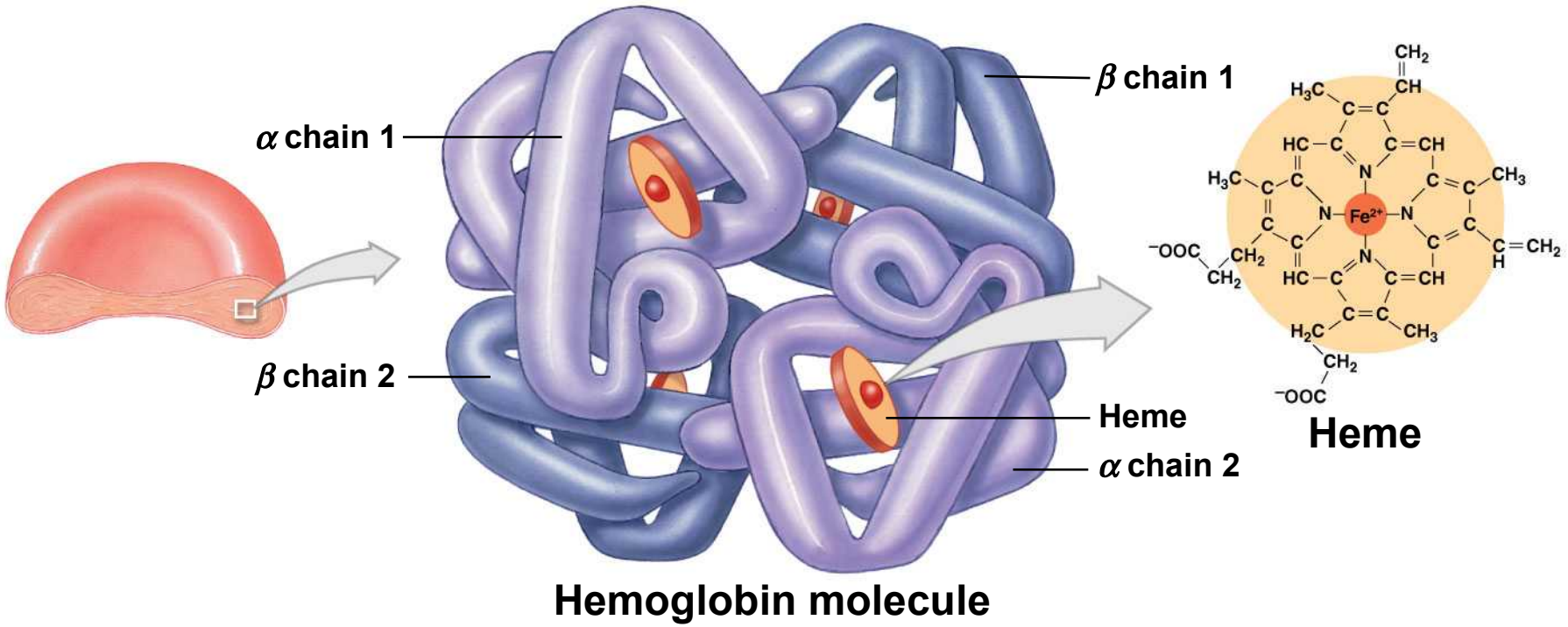
19-3 Red Blood Cells

- Hemoglobin Structure
  - Complex quaternary structure
  - Four globular protein subunits
    - Each with one molecule of **heme**
    - Each heme contains one iron ion

19-3 Red Blood Cells

- Hemoglobin Structure
  - Iron ions
    - Associate easily with oxygen (**oxyhemoglobin, HbO_2**)
    - Dissociate easily from oxygen (**deoxyhemoglobin**)

Figure 19-3 The Structure of Hemoglobin



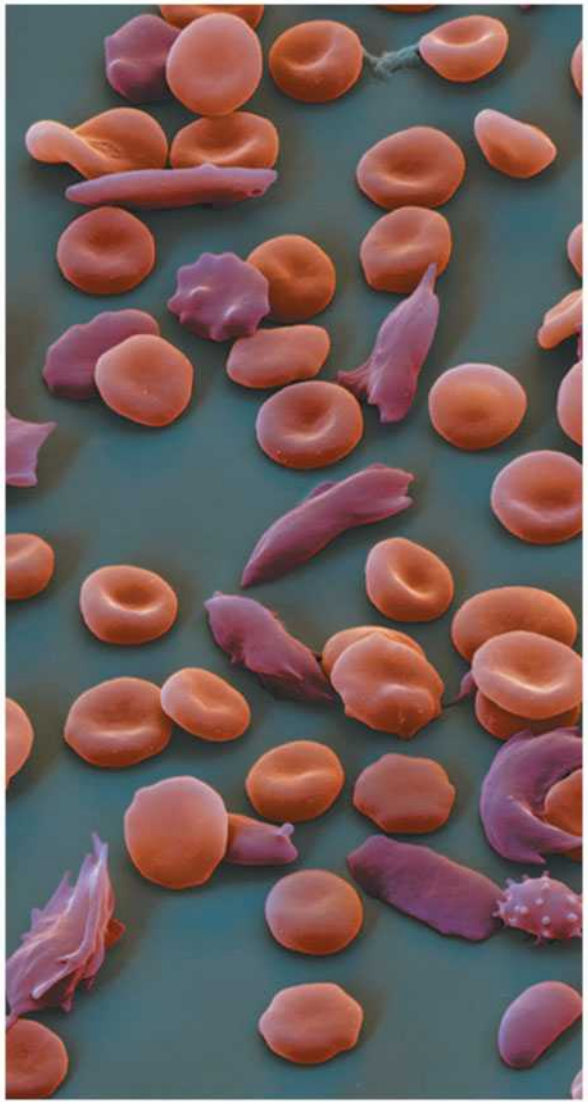
19-3 Red Blood Cells

- *Fetal Hemoglobin*
  - Strong form of hemoglobin found in embryos
  - Takes oxygen from mother's hemoglobin

19-3 Red Blood Cells

- Hemoglobin Function
  - Carries oxygen
  - With low oxygen (peripheral capillaries)
    - Hemoglobin releases oxygen
    - Binds carbon dioxide and carries it to lungs
      - Forms **carbaminohemoglobin**

Figure 19-4 “Sickling” in Red Blood Cells



19-3 Red Blood Cells

- RBC Formation and Turnover
  - 1% of circulating RBCs wear out per day
    - About 3 million RBCs per second
- Hemoglobin Conversion and Recycling
  - Macrophages of liver, spleen, and bone marrow
    - Monitor RBCs
    - Engulf RBCs before membranes rupture (hemolyze)

19-3 Red Blood Cells

- Hemoglobin Conversion and Recycling
  - Phagocytes break hemoglobin into components
    - Globular proteins to amino acids
    - Heme to **biliverdin**
    - Iron

19-3 Red Blood Cells

- Hemoglobin Conversion and Recycling
  - **Hemoglobinuria**
    - Hemoglobin breakdown products in urine due to excess hemolysis in bloodstream
  - **Hematuria**
    - Whole red blood cells in urine due to kidney or tissue damage

19-3 Red Blood Cells

- Breakdown of Biliverdin
  - Biliverdin (green) is converted to **bilirubin** (yellow)
    - Bilirubin
      - Is excreted by liver (bile)
      - **Jaundice** is caused by bilirubin buildup
      - Converted by intestinal bacteria to **urobilins** and **stercobilins**

19-3 Red Blood Cells

- Iron Recycling
  - Iron removed from heme leaving biliverdin
  - To transport proteins (**transferrin**)
  - To storage proteins (**ferritin** and **hemosiderin**)

Figure 19-5 Recycling of Red Blood Cell Components

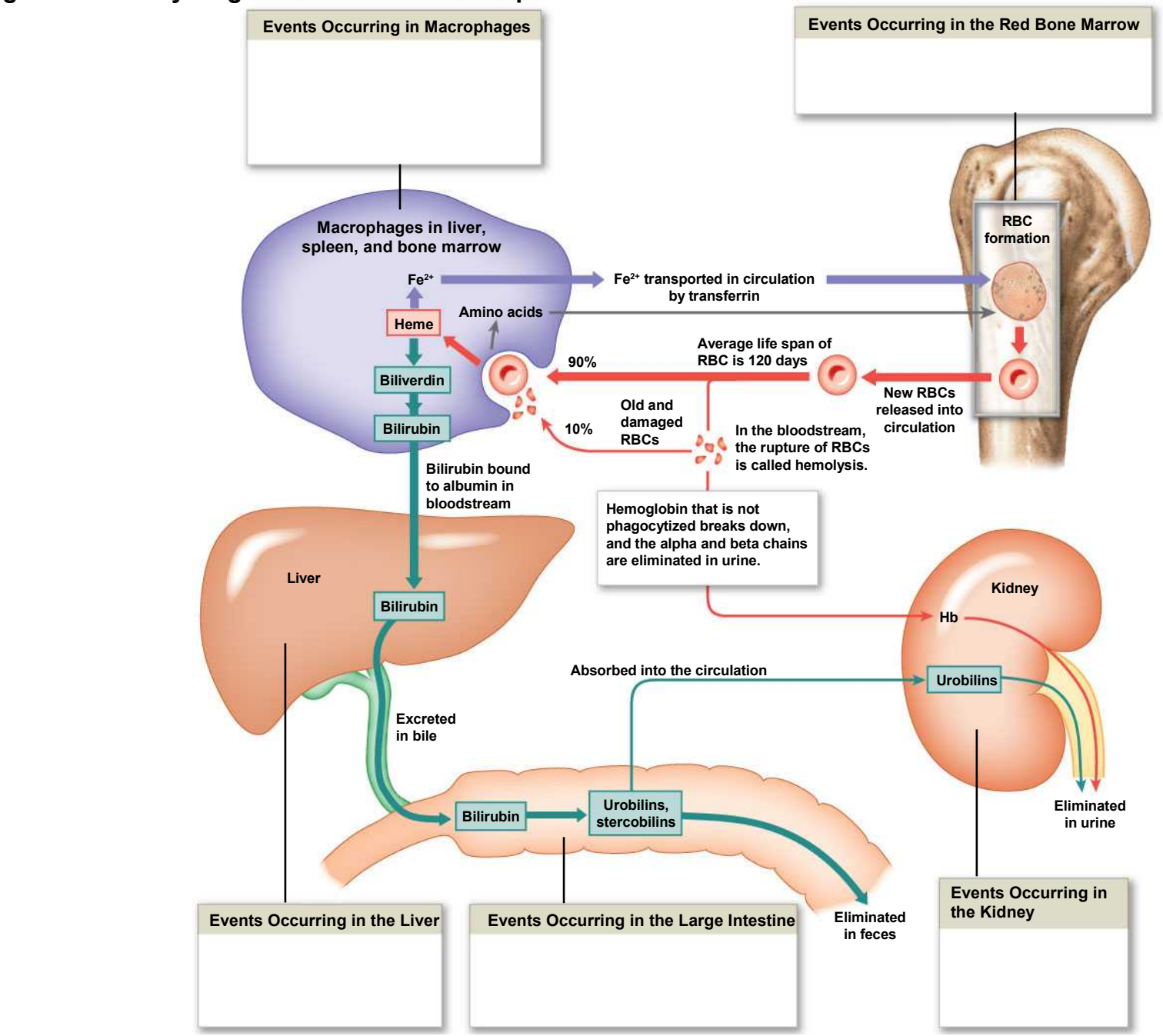


Figure 19-5 Recycling of Red Blood Cell Components

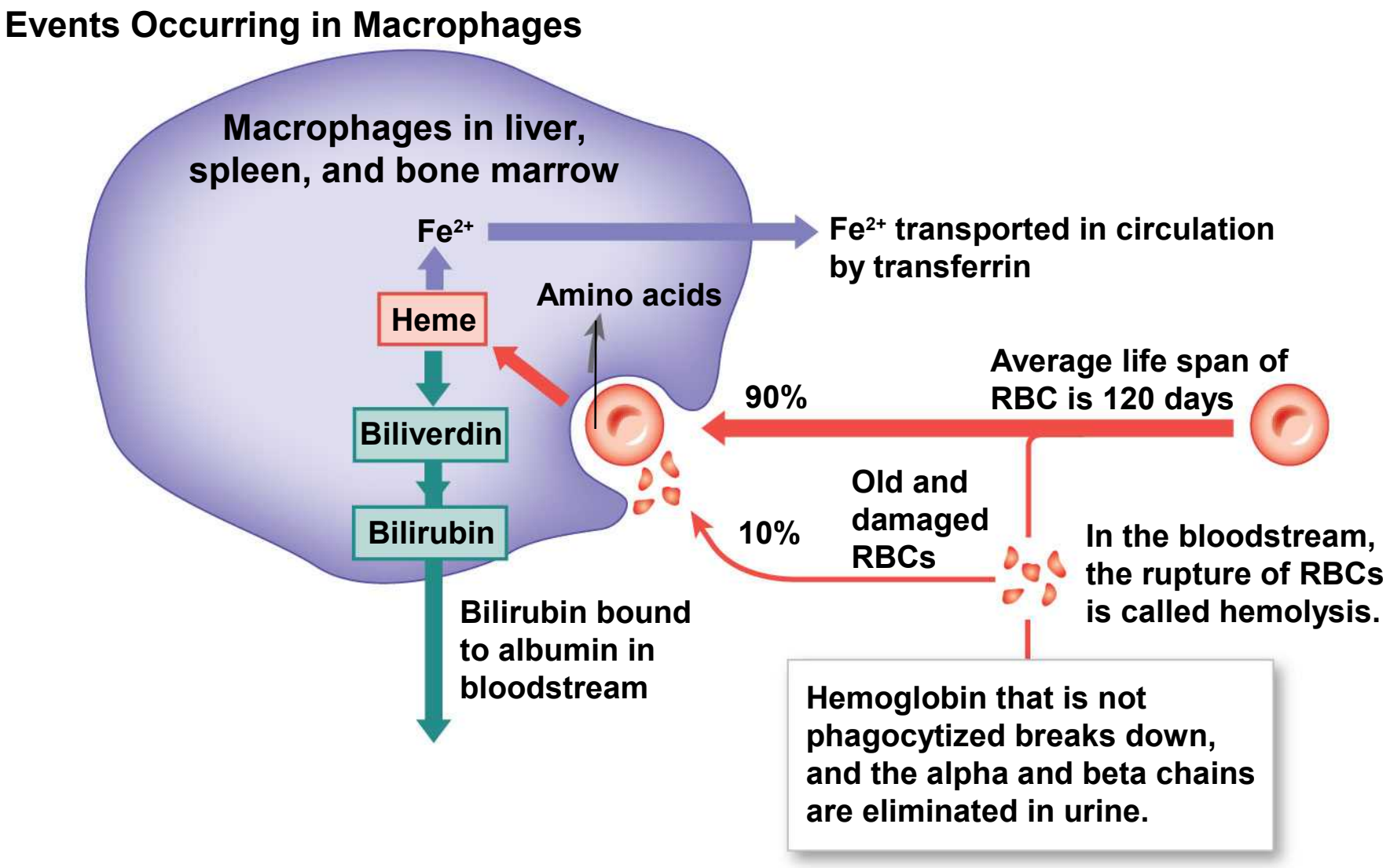


Figure 19-5 Recycling of Red Blood Cell Components

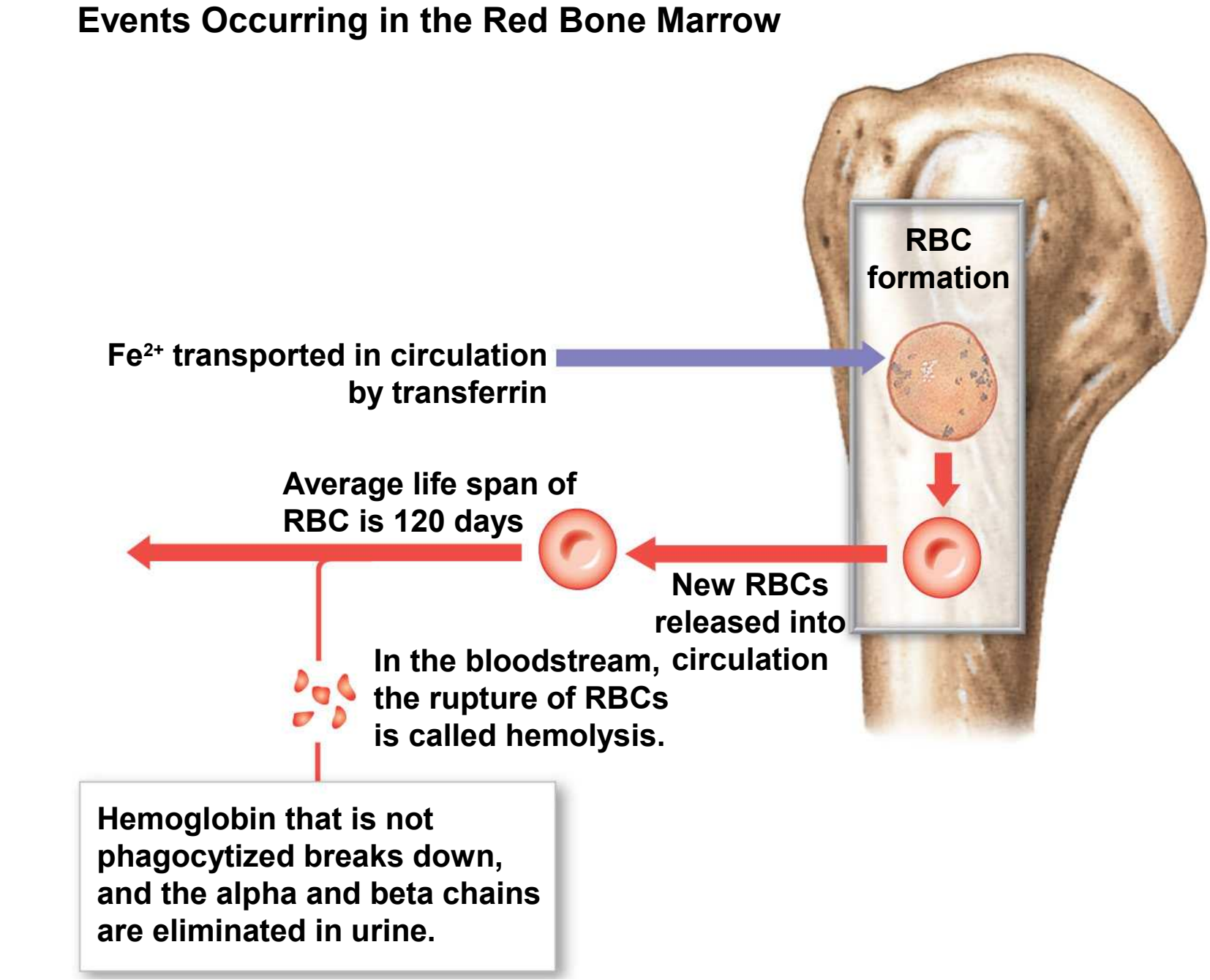
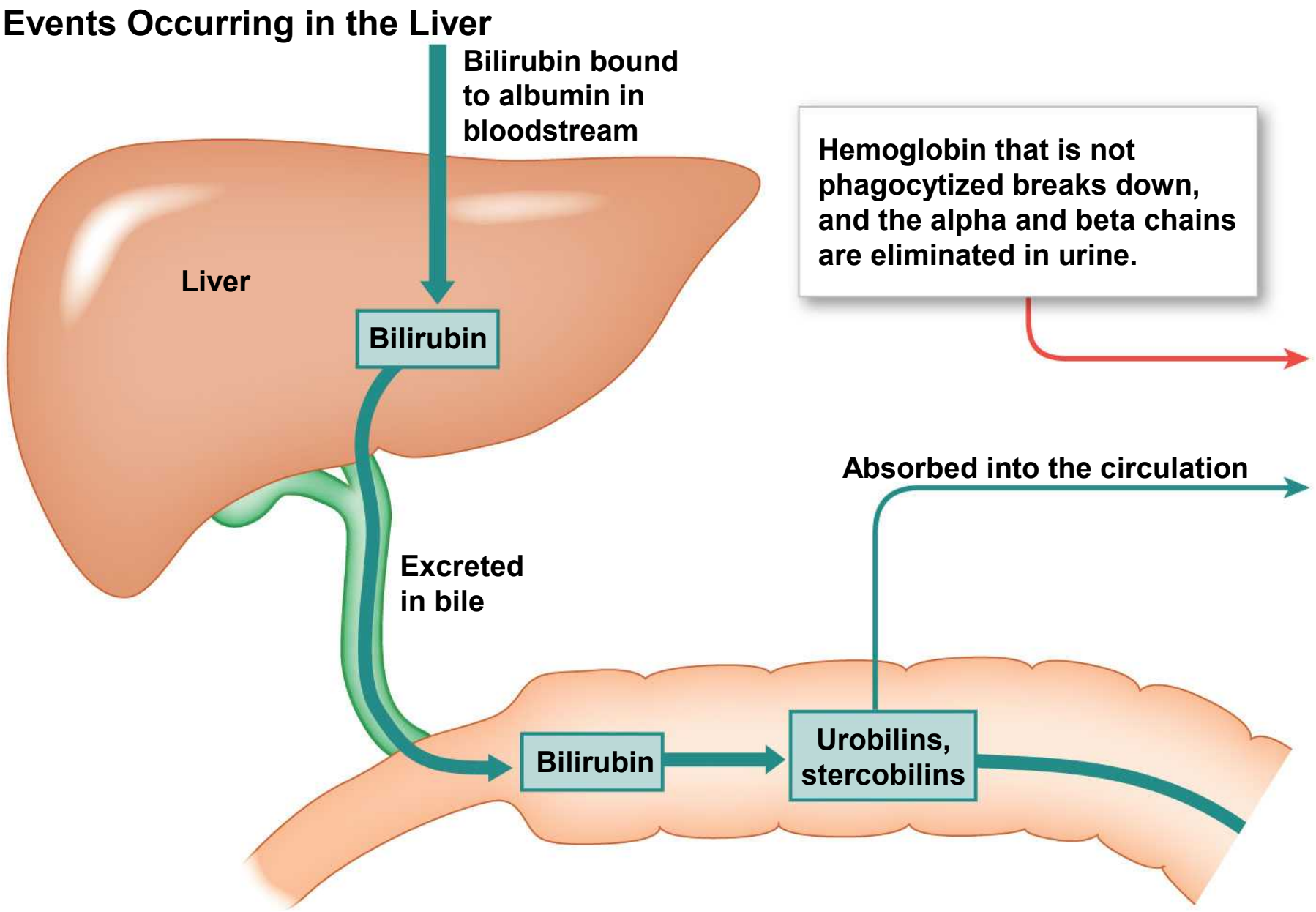


Figure 19-5 Recycling of Red Blood Cell Components



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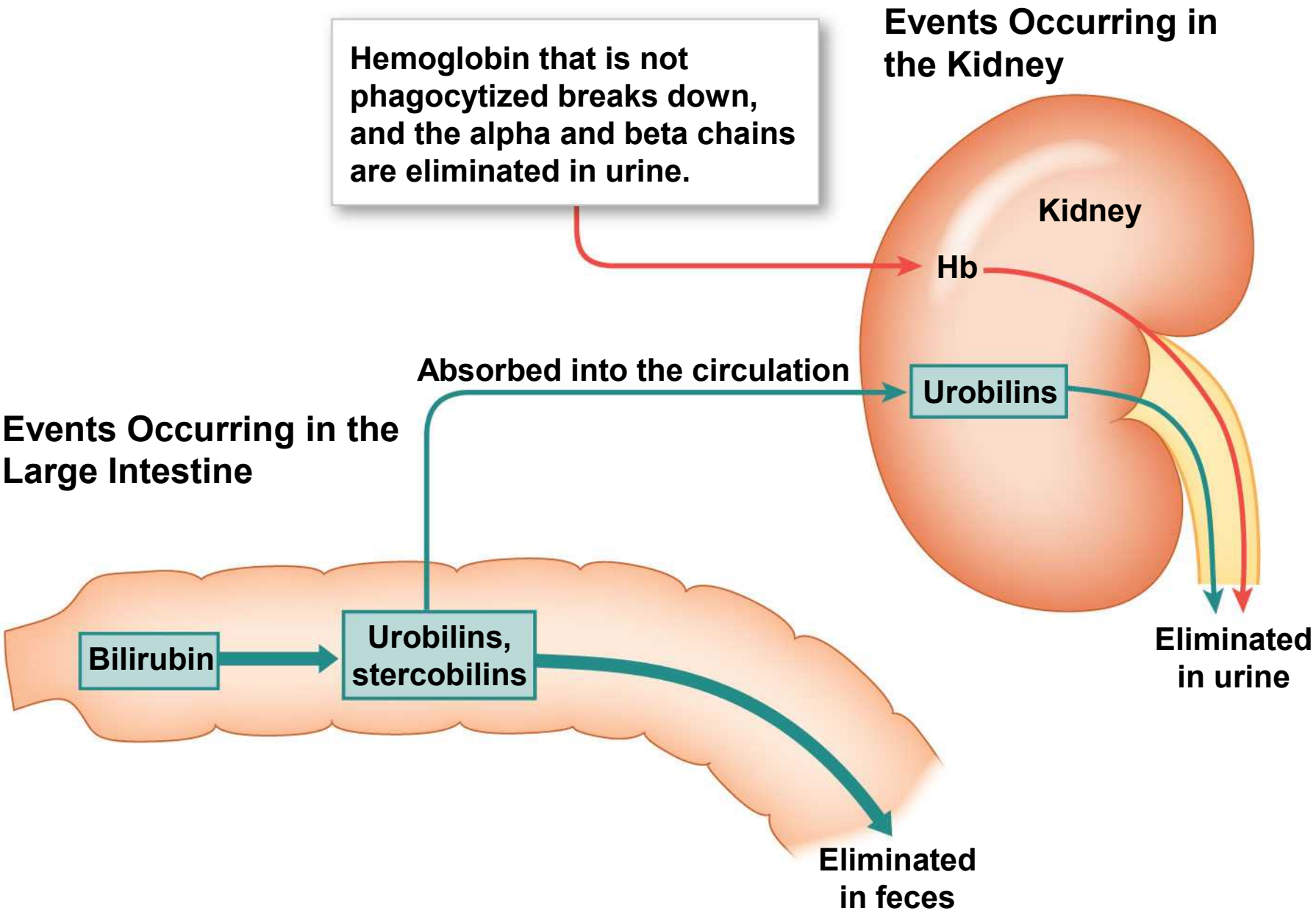


19-3 Red Blood Cells

- RBC Production
  - **Erythropoiesis**
    - Occurs only in **myeloid tissue** (*red bone marrow*) in adults
    - Stem cells mature to become RBCs

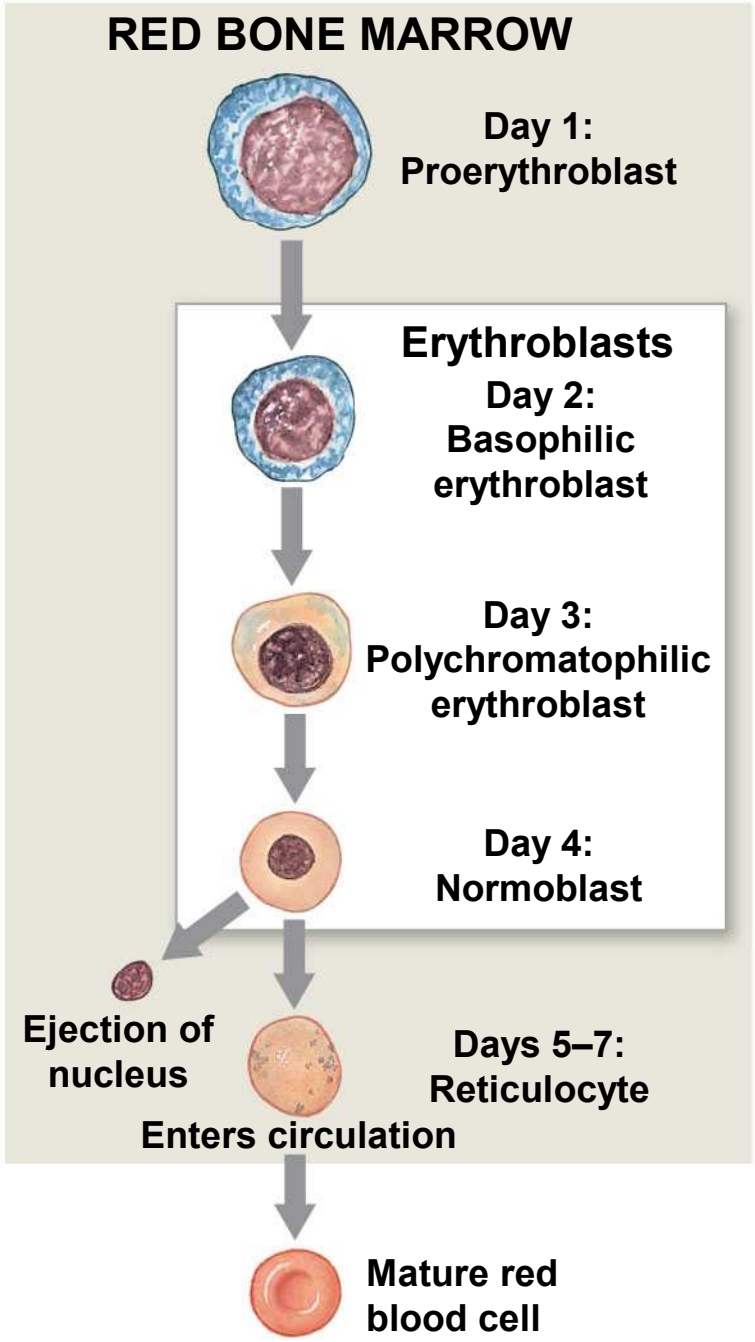
19-3 Red Blood Cells

- **Hemocytoblasts**
  - Stem cells in myeloid tissue divide to produce:
    1. **Myeloid stem cells** become RBCs, some WBCs
    2. **Lymphoid stem cells** become lymphocytes

19-3 Red Blood Cells

- Stages of RBC Maturation
  - **Myeloid stem cell**
  - **Proerythroblast**
  - **Erythroblasts**
  - **Reticulocyte**
  - Mature RBC

Figure 19-6 Stages of RBC Maturation



19-3 Red Blood Cells

- Regulation of Erythropoiesis
  - Building red blood cells requires:
    - Amino acids
    - Iron
    - Vitamins B_{12}, B_6, and folic acid
      - *Pernicious anemia*
        - Low RBC production
        - Due to unavailability of vitamin B_{12}

19-3 Red Blood Cells

- Stimulating Hormones
  - **Erythropoietin (EPO)**
    - Also called **erythropoiesis-stimulating hormone**
    - Secreted when oxygen in peripheral tissues is low (**hypoxia**)
    - Due to disease or high altitude

Table 19-1 RBC Tests and Related Terminology

Table 19–1 RBC Tests and Related Terminology

Test	Determines	Terms Associated with Abnormal Values: Elevated	Terms Associated with Abnormal Values: Depressed
Hematocrit (Hct)	Percentage of formed elements in whole blood Normal = 37–54%	Polycythemia (may reflect erythrocytosis or leukocytosis)	Anemia
Reticulocyte count (Retic.)	Percentage of circulating reticulocytes Normal = 0.8%	Reticulocytosis	
Hemoglobin concentration (Hb)	Concentration of hemoglobin in blood Normal =12–18 g/dL		Anemia
RBC count	Number of RBCs per µL of whole blood Normal = 4.2–6.3 million/μL	Erythrocytosis/polycythemia	Anemia
Mean corpuscular volume (MCV)	Average volume of single RBC Normal = 82–101 μm^3 (normocytic)	Macrocytic	Microcytic
Mean corpuscular hemoglobin concentration (MCHC)	Average amount of Hb in one RBC Normal = 27–34 pg/μL (normochromic)	Hyperchromic	Hypochromic

Table 19-3 Formed Elements of the Blood

Table 19–3 Formed Elements of the Blood

Cell	Abundance (average number per μL)	Appearance in a Stained Blood Smear	Functions	Remarks
RED BLOOD CELLS 	5.2 million (range: 4.4–6.0 million)	Flattened, circular cell; no nucleus, mitochondria, or ribosomes; red	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

19-4 Blood Typing

- **Surface Antigens**
  - Are cell surface proteins that identify cells to immune system
  - Normal cells are ignored and foreign cells attacked
- **Blood Types**
  - Are genetically determined
  - By presence or absence of RBC surface antigens **A, B, Rh** (or **D**)

19-4 Blood Typing

- Four Basic Blood Types
  1. **A** (surface antigen A)
  2. **B** (surface antigen B)
  3. **AB** (antigens A and B)
  4. **O** (neither A nor B)

19-4 Blood Typing

- **Agglutinogens**
  - Antigens on surface of RBCs
  - Screened by immune system
  - Plasma antibodies attack and **agglutinate** (clump) foreign antigens

19-4 Blood Typing

- Blood Plasma Antibodies
  - Type A
    - Type B antibodies
  - Type B
    - Type A antibodies
  - Type O
    - Both A and B antibodies
  - Type AB
    - Neither A nor B antibodies

Figure 19-7a Blood Types and Cross-Reactions

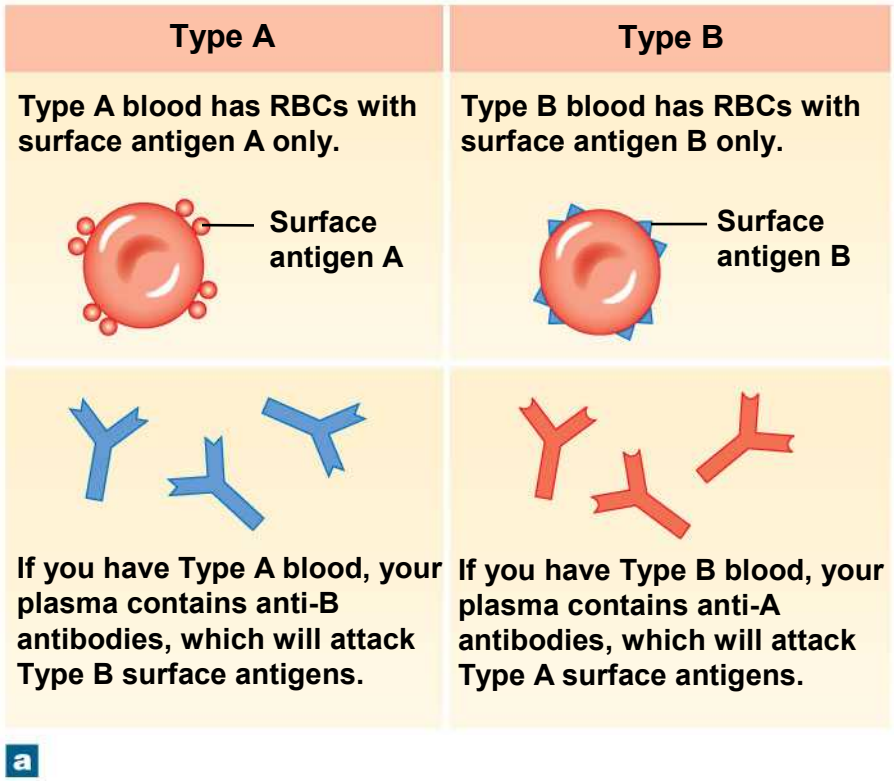


Figure 19-7a Blood Types and Cross-Reactions

Type AB	Type O
Type AB blood has RBCs with both A and B surface antigens. 	Type O blood has RBCs lacking both A and B surface antigens. 
If you have Type AB blood, your plasma has neither anti-A nor anti-B antibodies.	 If you have Type O blood, your plasma contains both anti-A and anti-B antibodies.

19-4 Blood Typing

- The *Rh Factor*
  - Also called D antigen
  - Either **Rh positive** (Rh^+) or **Rh negative** (Rh^-)
    - Only **sensitized** Rh^- blood has anti-Rh antibodies

Figure 19-9 Hemolytic Disease of the Newborn

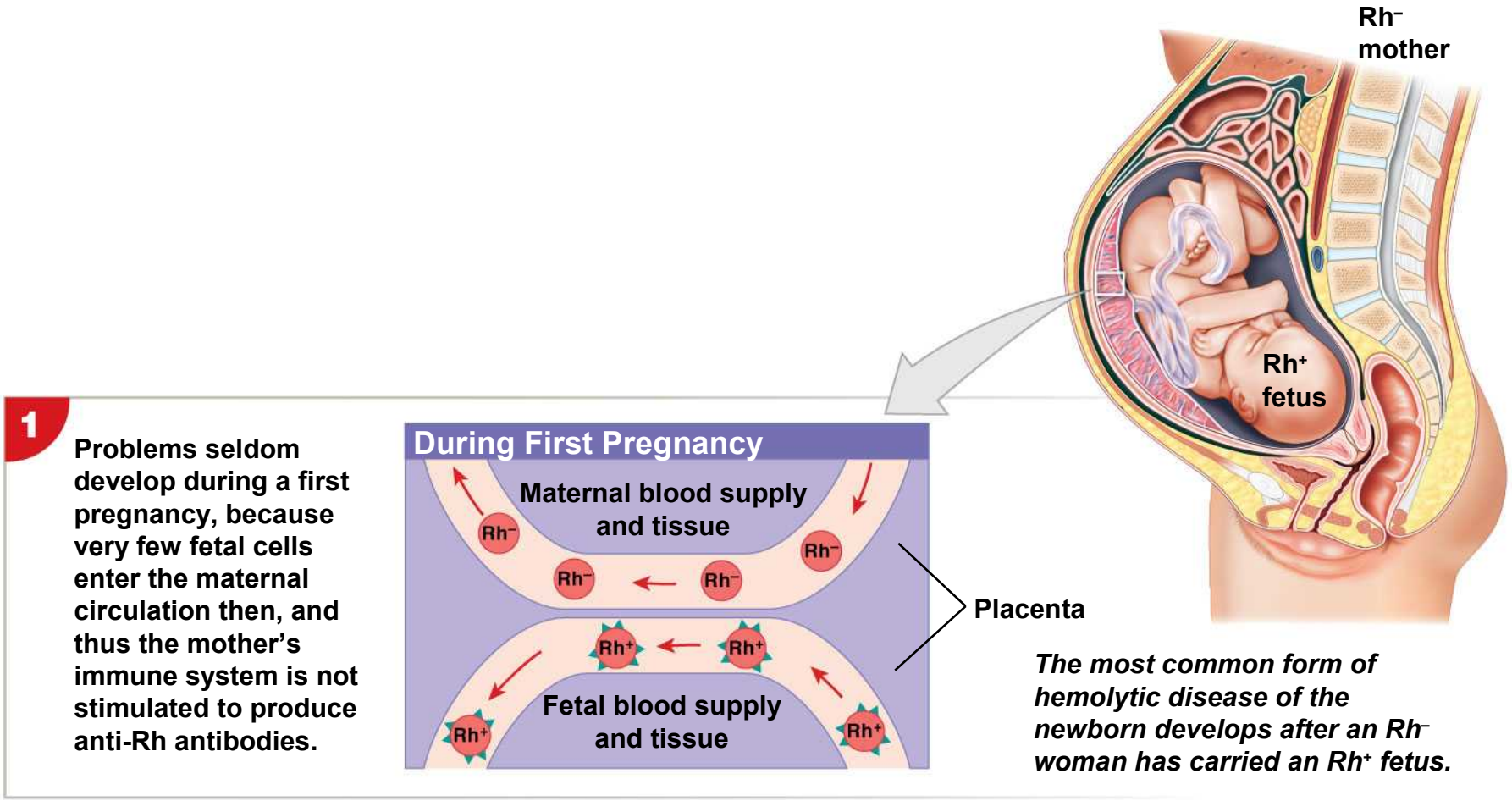


Figure 19-9 Hemolytic Disease of the Newborn

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Exposure to fetal red blood cell antigens generally occurs during delivery, when bleeding takes place at the placenta and uterus. Such mixing of fetal and maternal blood can stimulate the mother's immune system to produce anti-Rh antibodies, leading to sensitization.

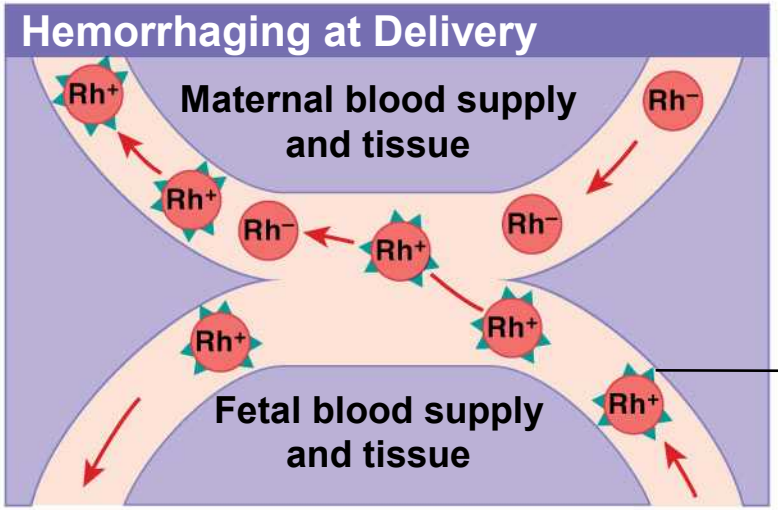


Figure 19-9 Hemolytic Disease of the Newborn

3

Roughly 20% of Rh^- mothers who carried Rh^+ children become sensitized within 6 months of delivery. Because the anti-Rh antibodies are not produced in significant amounts until after delivery, a woman's first infant is not affected.

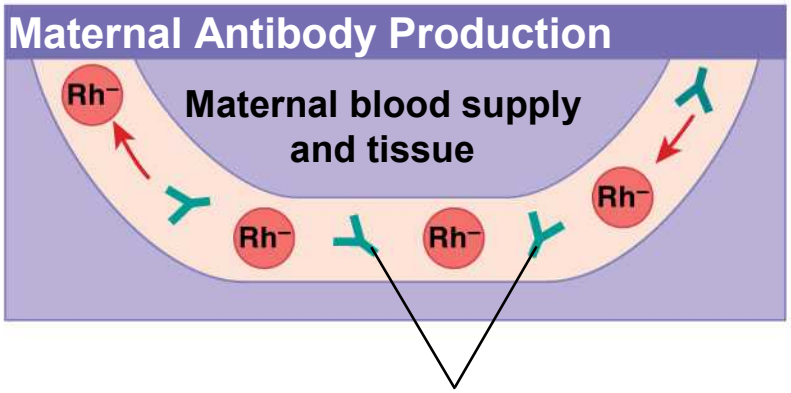
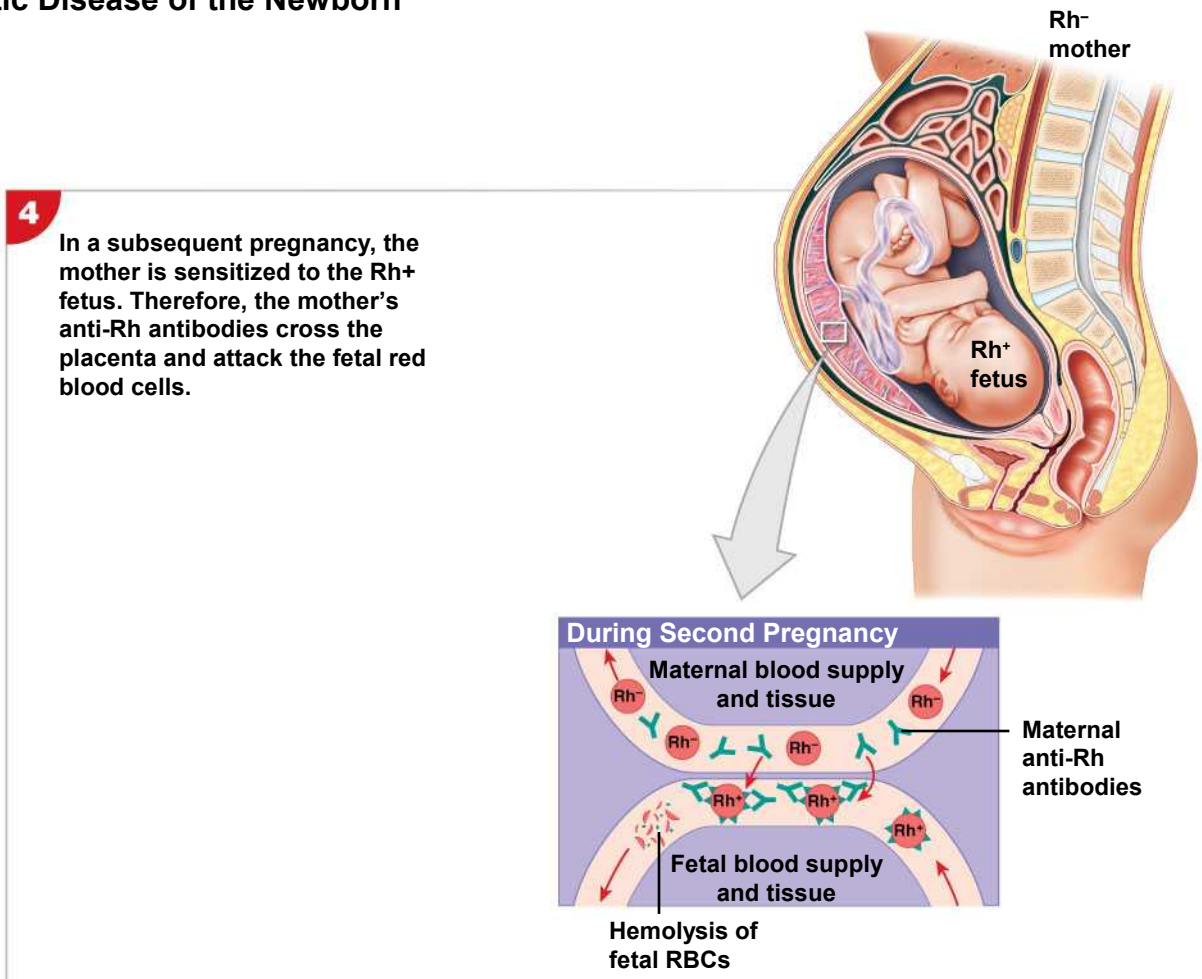


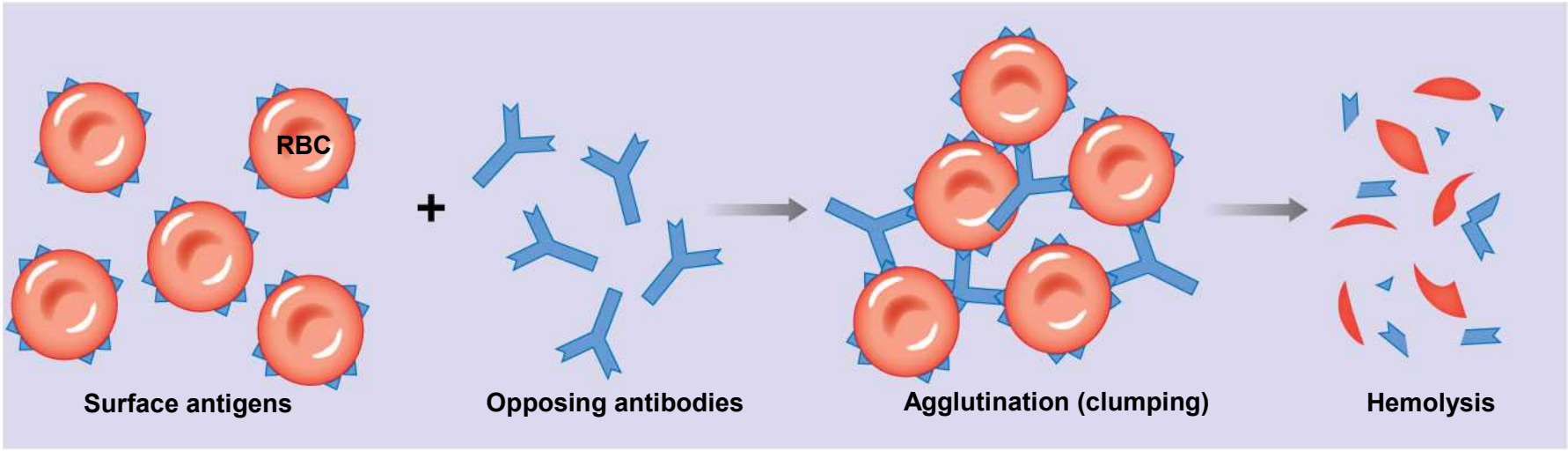
Figure 19-9 Hemolytic Disease of the Newborn



19-4 Blood Typing

- Cross-Reactions in Transfusions
  - Also called *transfusion reaction*
  - Plasma antibody meets its specific surface antigen
  - Blood will agglutinate and hemolyze
  - Occur if donor and recipient blood types not **compatible**

Figure 19-7b Blood Types and Cross-Reactions



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

19-4 Blood Typing

- Testing for Transfusion Compatibility
  - Performed on donor and recipient blood for compatibility
  - Without **cross-match**, type O^- is universal donor

Figure 19-8 Blood Type Testing

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

Table 19-2 Differences in Blood Group Distribution

Table 19–2 Differences in Blood Group Distribution

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

19-5 White Blood Cells

- White Blood Cells (WBCs)
  - Also called leukocytes
  - Do not have hemoglobin
  - Have nuclei and other organelles
  - WBC functions:
    - Defend against pathogens
    - Remove toxins and wastes
    - Attack abnormal cells

19-5 White Blood Cells

- WBC Circulation and Movement
  - Most WBCs in:
    - Connective tissue proper
    - Lymphatic system organs
  - Small numbers in blood
    - 5000 to 10,000 per microliter

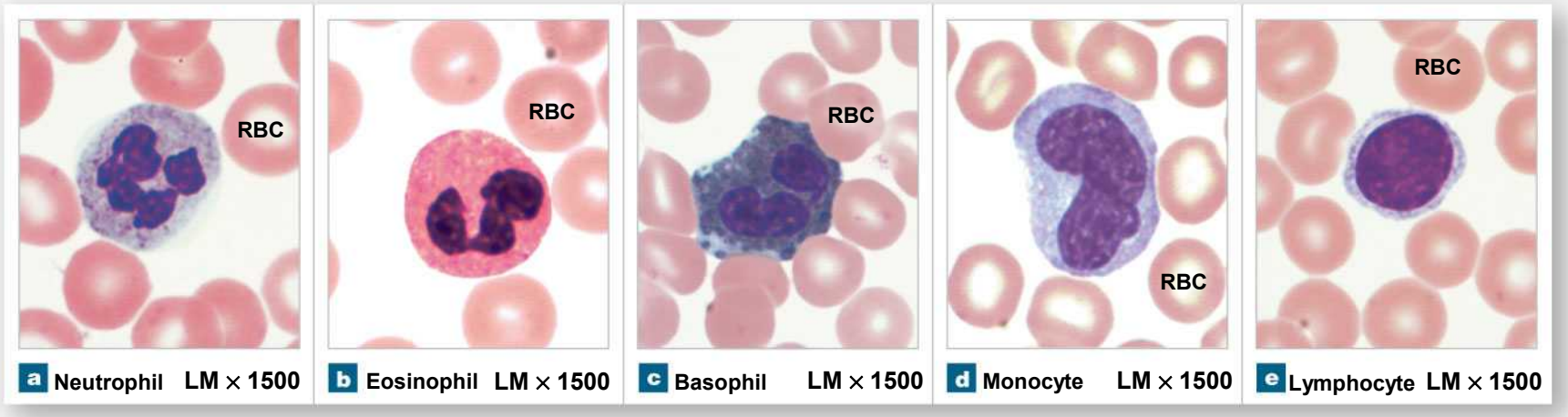
19-5 White Blood Cells

- WBC Circulation and Movement
  - Four Characteristics of Circulating WBCs
    1. Can migrate out of bloodstream
    2. Have amoeboid movement
    3. Attracted to chemical stimuli (**positive chemotaxis**)
    4. Some are phagocytic
       - *Neutrophils, eosinophils,* and *monocytes*

19-5 White Blood Cells

- Types of WBCs
  - **Neutrophils**
  - **Eosinophils**
  - **Basophils**
  - **Monocytes**
  - **Lymphocytes**

Figure 19-10 White Blood Cells



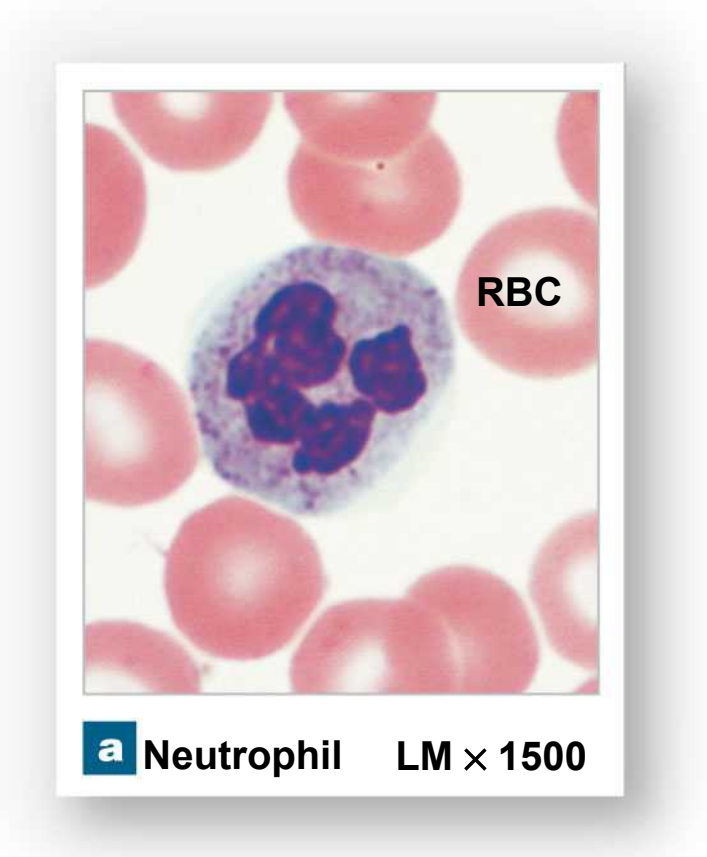
19-5 White Blood Cells

- **Neutrophils**
  - Also called **polymorphonuclear leukocytes**
  - 50–70% of circulating WBCs
  - Pale cytoplasm granules with:
    - Lysosomal enzymes
    - Bactericides (hydrogen peroxide and superoxide)

19-5 White Blood Cells

- Neutrophil Action
  - Very active, first to attack bacteria
  - Engulf and digest pathogens
  - **Degranulation**
    - Removing granules from cytoplasm
    - **Defensins** (peptides from lysosomes) attack pathogen membranes
  - Release prostaglandins and leukotrienes
  - Form *pus*

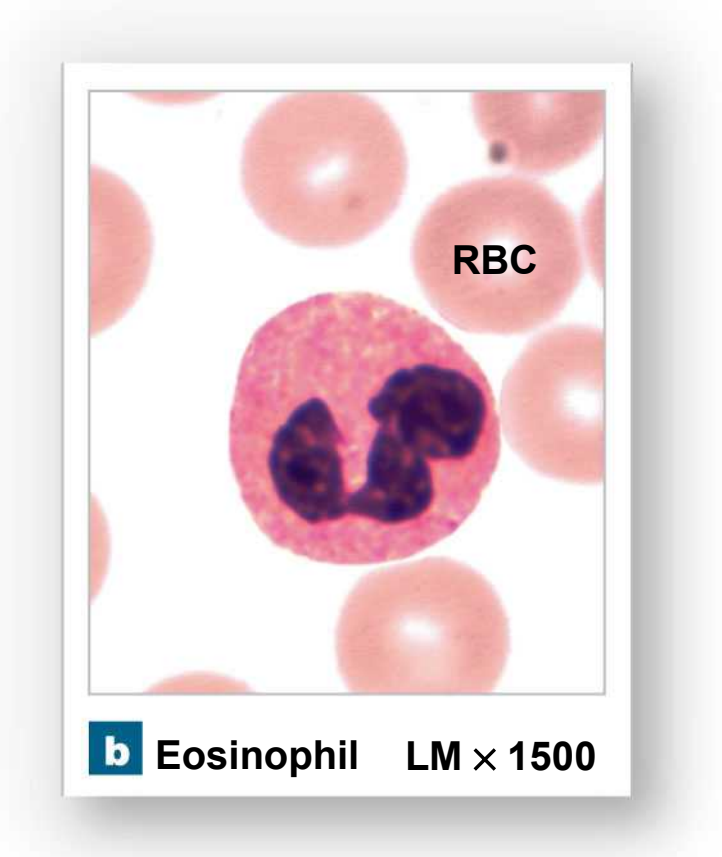
Figure 19-10a White Blood Cells



19-5 White Blood Cells

- **Eosinophils (Acidophils)**
  - 2–4% of circulating WBCs
  - Attack large parasites
  - Excrete toxic compounds
    - Nitric oxide
    - Cytotoxic enzymes
  - Are sensitive to *allergens*
  - Control inflammation with enzymes that counteract inflammatory effects of neutrophils and mast cells

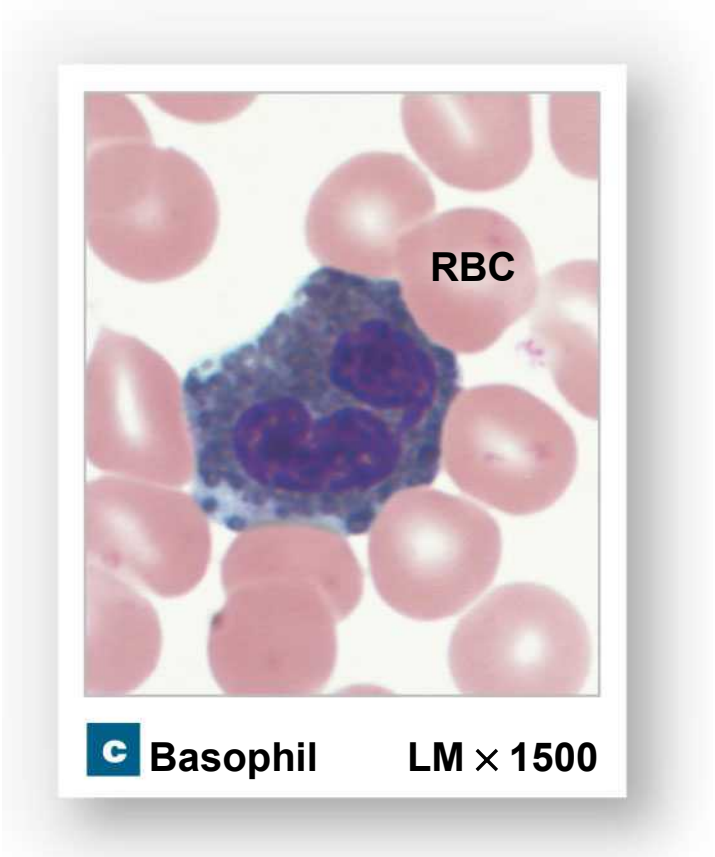
Figure 19-10b White Blood Cells



19-5 White Blood Cells

- **Basophils**
  - Are less than 1% of circulating WBCs
  - Accumulate in damaged tissue
  - Release *histamine*
    - Dilates blood vessels
  - Release *heparin*
    - Prevents blood clotting

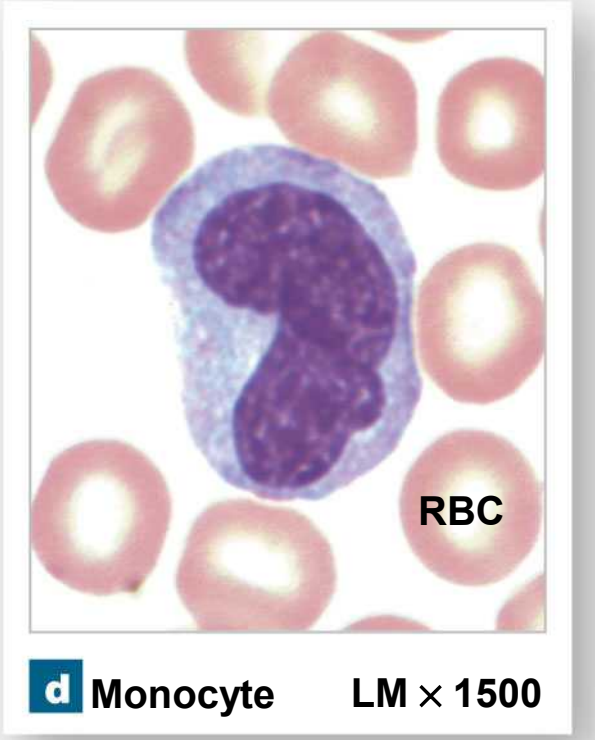
Figure 19-10c White Blood Cells



19-5 White Blood Cells

- **Monocytes**
  - 2–8% of circulating WBCs
  - Are large and spherical
  - Enter peripheral tissues and become macrophages
  - Engulf large particles and pathogens
  - Secrete substances that attract immune system cells and fibrocytes to injured area

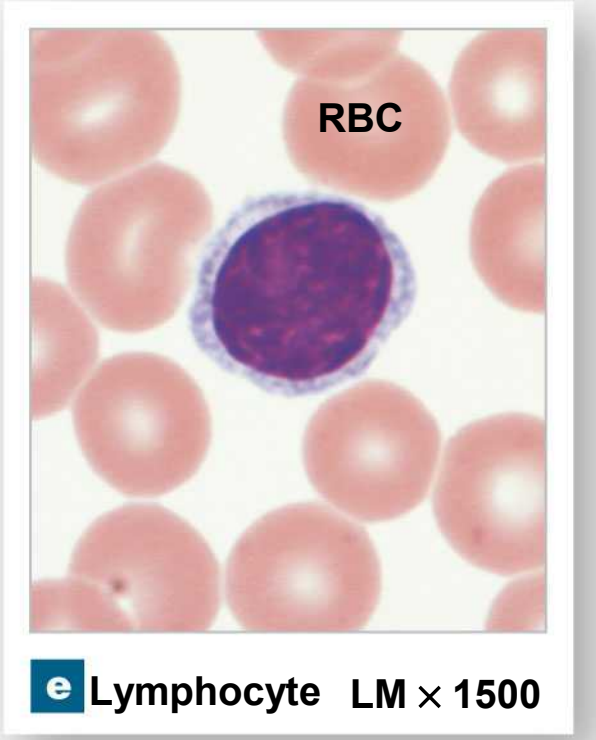
Figure 19-10d White Blood Cells



19-5 White Blood Cells

- **Lymphocytes**
  - 20–30% of circulating WBCs
  - Are larger than RBCs
  - Migrate in and out of blood
  - Mostly in connective tissues and lymphoid organs
  - Are part of the body's specific defense system

Figure 19-10e White Blood Cells



19-5 White Blood Cells

- Three Classes of Lymphocytes
  1. **T cells**
     - *Cell-mediated immunity*
     - Attack foreign cells directly

19-5 White Blood Cells

- Three Classes of Lymphocytes
  2. **B cells**
     - *Humoral immunity*
     - Differentiate into **plasma cells**
     - Synthesize antibodies
  2. **Natural killer (NK) cells**
     - Detect and destroy abnormal tissue cells (cancers)

19-5 White Blood Cells

- The **Differential Count** and Changes in WBC Profiles
  - Detects changes in WBC populations
  - Infections, inflammation, and allergic reactions

19-5 White Blood Cells

- WBC Disorders
  - **Leukopenia**
    - Abnormally low WBC count
  - **Leukocytosis**
    - Abnormally high WBC count
  - **Leukemia**
    - Extremely high WBC count

19-5 White Blood Cells

- WBC Production
  - All blood cells originate from hemocytoblasts
    - Which produce **progenitor cells** called myeloid stem cells and lymphoid stem cells

19-5 White Blood Cells

- WBC Production
  - Myeloid Stem Cells
    - Produce all WBCs except lymphocytes
  - Lymphoid Stem Cells
    - **Lymphopoiesis -** the production of lymphocytes

19-5 White Blood Cells

- WBC Development
  - WBCs, except monocytes
    - Develop in bone marrow
  - Monocytes
    - Develop into macrophages in peripheral tissues

19-5 White Blood Cells

- Regulation of WBC Production
  - **Colony-stimulating factors (CSFs)**
    - Hormones that regulate blood cell populations
      1. **M-CSF** stimulates monocyte production
      2. **G-CSF** stimulates production of granulocytes (neutrophils, eosinophils, and basophils)
      3. **GM-CSF** stimulates granulocyte and monocyte production
      4. **Multi-CSF** accelerates production of granulocytes, monocytes, platelets, and RBCs

Table 19-3 Formed Elements of the Blood

Table 19–3 Formed Elements of the Blood

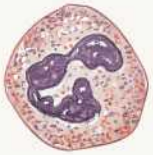
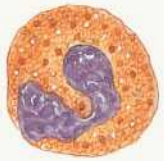
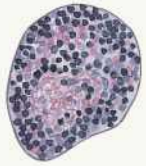
Cell	Abundance (average number per μL)	Appearance in a Stained Blood Smear	Functions	Remarks
WHITE BLOOD CELLS	7000 (range: 5000–10,000)			
Neutrophils 	4150 (range: 1800–7300) Differential count: 50–70%	Round cell; nucleus lobed and may resemble a string of beads; cytoplasm contains large, pale inclusions	Phagocytic: Engulf pathogens or debris in tissues, release cytotoxic enzymes and chemicals	Move into tissues after several hours; may survive minutes to days, depending on tissue activity; produced in red bone marrow
Eosinophils 	165 (range: 0–700) Differential count: 2–4%	Round cell; nucleus generally in two lobes; cytoplasm contains large granules that generally stain bright red	Phagocytic: Engulf antibody-labeled materials, release cytotoxic enzymes, reduce inflammation; increase in 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%	Round cell; nucleus generally cannot be seen through dense, blue-stained granules in cytoplasm	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 19-3 Formed Elements of the Blood

Table 19–3 Formed Elements of the Blood

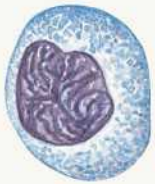
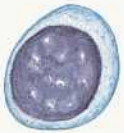
Cell	Abundance (average number per μL)	Appearance in a Stained Blood Smear	Functions	Remarks
WHITE BLOOD CELLS	7000 (range: 5000–10,000)			
Monocytes 	456 (range: 200–950) Differential count: 2–8%	Very large cell; kidney bean–shaped nucleus; abundant pale cytoplasm	Enter tissues to become macrophages; engulf pathogens or debris	Move into tissues after 1–2 days; survive for months or longer; produced primarily in red bone marrow
Lymphocytes 	2185 (range: 1500–4000) Differential count: 20–30%	Generally round cell, slightly larger than RBC; round nucleus; very little cytoplasm	Cells of lymphatic system, providing defense against specific pathogens or toxins	Survive for months to decades; circulate from blood to tissues and back; produced in red bone marrow and lymphatic tissues

Figure 19-11 The Origins and Differentiation of Formed Elements

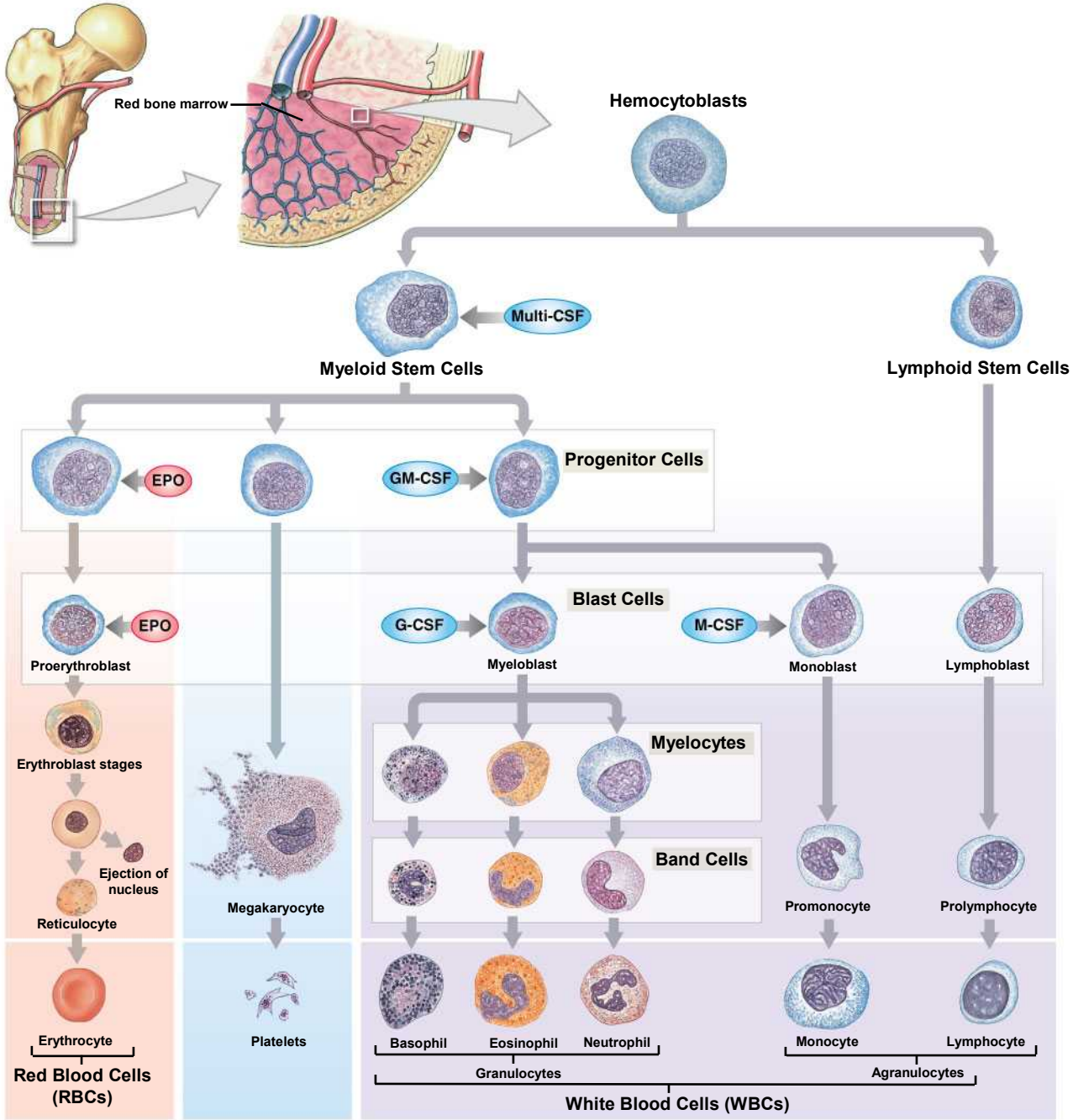


Figure 19-11 The Origins and Differentiation of Formed Elements

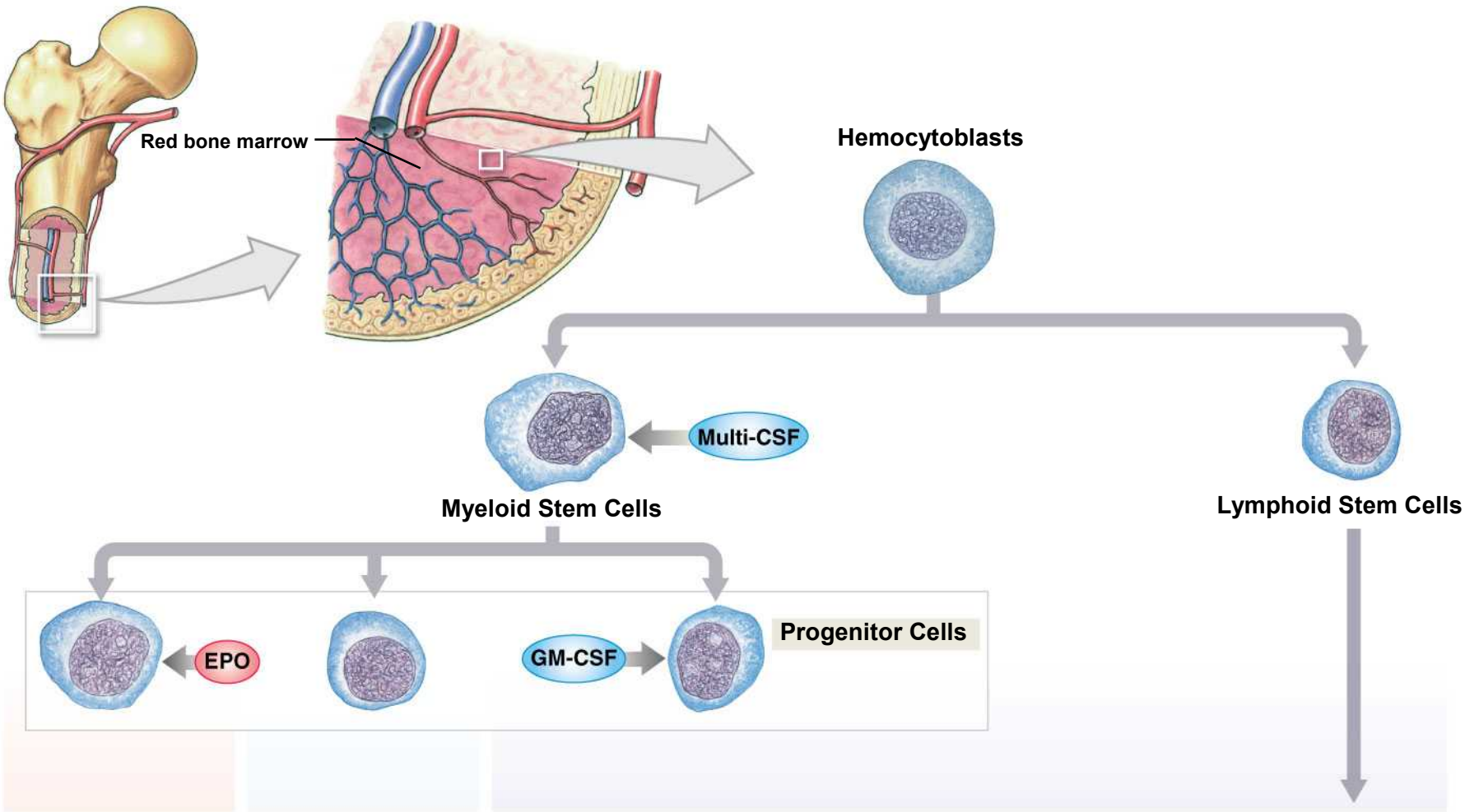


Figure 19-11 The Origins and Differentiation of Formed Elements

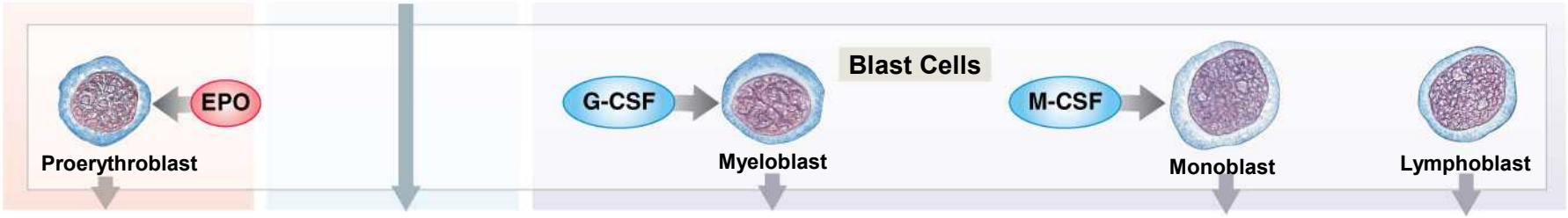


Figure 19-11 The Origins and Differentiation of Formed Elements

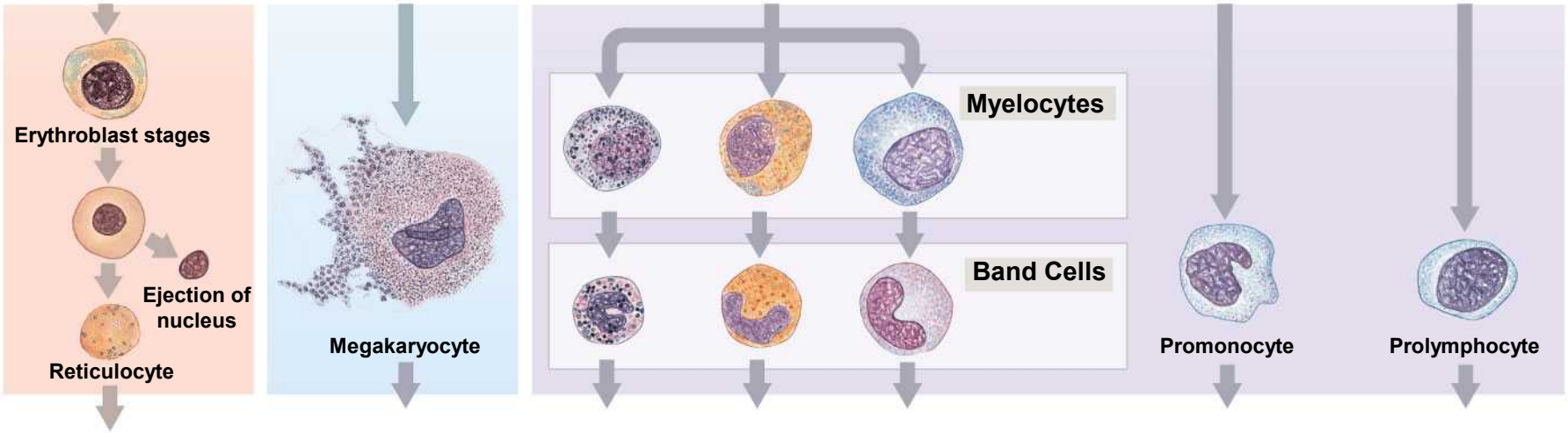
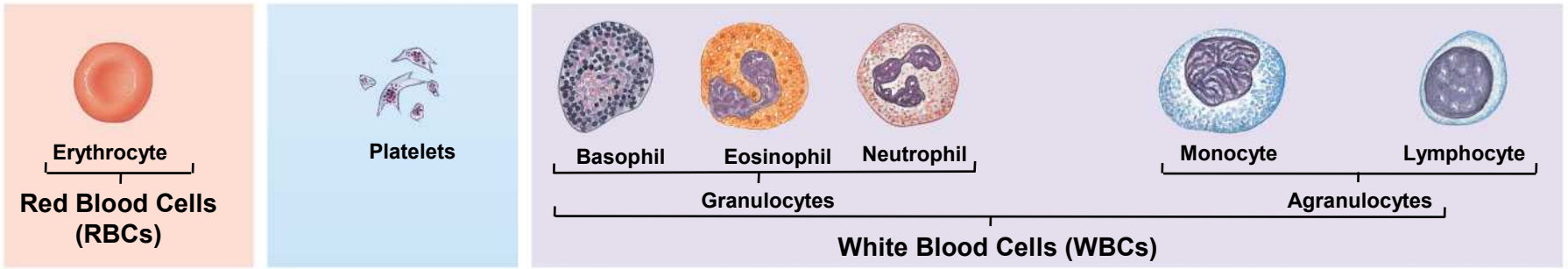


Figure 19-11 The Origins and Differentiation of Formed Elements



19-6 Platelets

- Platelets
  - Cell fragments involved in human clotting system
    - Nonmammalian vertebrates have **thrombocytes** (nucleated cells)
  - Circulate for 9–12 days
  - Are removed by spleen
  - 2/3 are reserved for emergencies

19-6 Platelets

- Platelet Counts
  - 150,000 to 500,000 per microliter
  - **Thrombocytopenia**
    - Abnormally low platelet count
  - **Thrombocytosis**
    - Abnormally high platelet count

19-6 Platelets

- Three Functions of Platelets
  1. Release important clotting chemicals
  2. Temporarily patch damaged vessel walls
  3. Reduce size of a break in vessel wall

19-6 Platelets

- Platelet Production
  - Also called **thrombocytopoiesis**
    - Occurs in bone marrow
  - **Megakaryocytes**
    - Giant cells in bone marrow
    - Manufacture platelets from cytoplasm

19-6 Platelets

- Platelet Production
  - Hormonal controls
    1. *Thrombopoietin* (TPO)
    2. *Interleukin-6* (IL-6)
    3. Multi-CSF

Table 19-3 Formed Elements of the Blood

Table 19–3 Formed Elements of the Blood

Cell	Abundance (average number per μL)	Appearance in a Stained Blood Smear	Functions	Remarks
PLATELETS 	350,000 (range: 150,000–500,000)	Round to spindle-shaped cytoplasmic fragment; contain enzymes, proenzymes, actin, and myosin; no nucleus	Hemostasis: Clump together and stick to vessel wall (platelet phase); activate intrinsic pathway of coagulation phase	Remain in bloodstream or in vascular organs; remain intact for 7–12 days; produced by megakaryocytes in red bone marrow

19-7 Hemostasis

- **Hemostasis**
  - Is the cessation of bleeding
  - Consists of three phases
    1. **Vascular phase**
    2. **Platelet phase**
    3. **Coagulation phase**

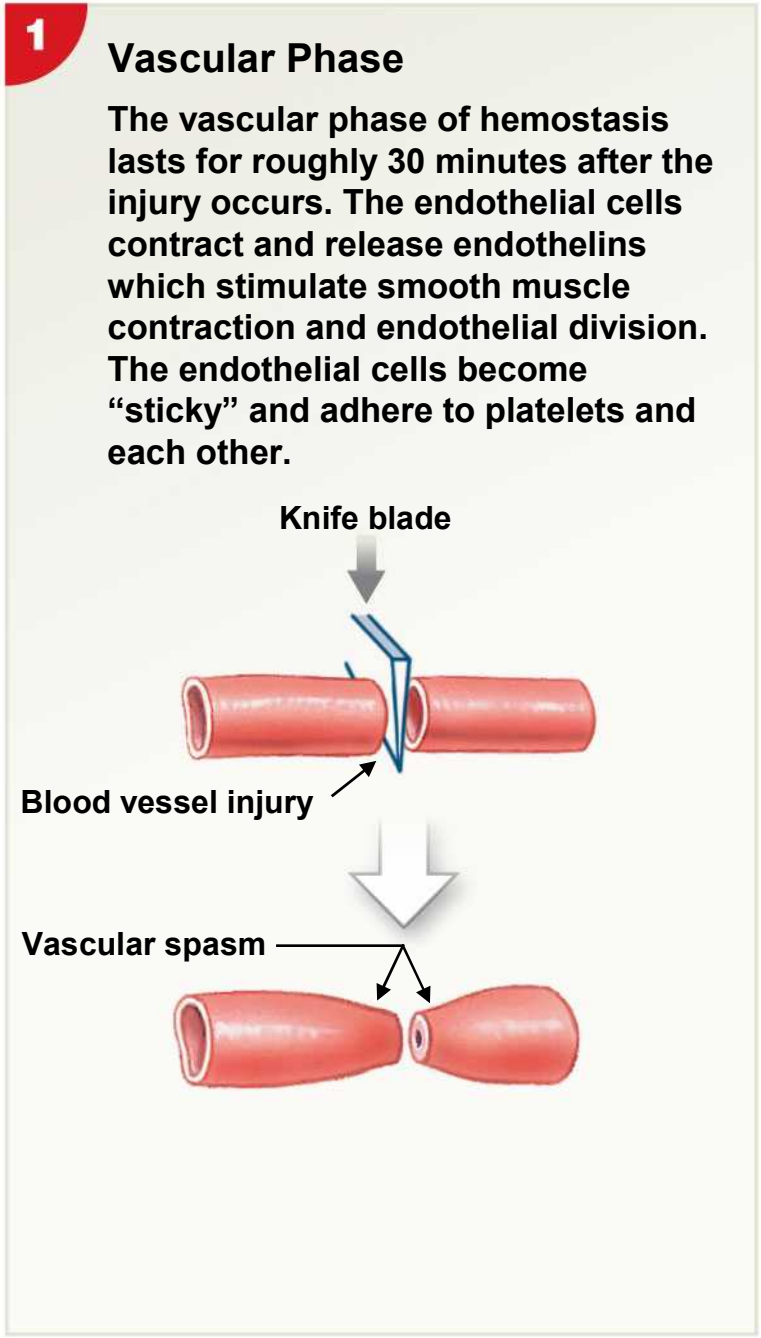
19-7 Hemostasis

- The **Vascular Phase**
  - A cut triggers vascular spasm that lasts 30 minutes
  - Three Steps of the Vascular Phase
    1. *Endothelial cells contract and expose basement membrane to bloodstream*

19-7 Hemostasis

- Three Steps of the Vascular Phase
  2. *Endothelial cells*
     - Release chemical factors ADP, tissue factor, and prostacyclin
     - Release local hormones, **endothelins**
     - Stimulate smooth muscle contraction and cell division
  3. *Endothelial plasma membranes become "sticky"*
     - Seal off blood flow

Figure 19-12 The Vascular, Platelet, and Coagulation Phases of Hemostasis and Clot Retraction (Step 1)



19-7 Hemostasis

- The **Platelet Phase**
  - Begins within 15 seconds after injury
  - **Platelet adhesion** (attachment)
    - To sticky endothelial surfaces
    - To basement membranes
    - To exposed collagen fibers
  - **Platelet aggregation** (stick together)
    - Forms **platelet plug** which closes small breaks

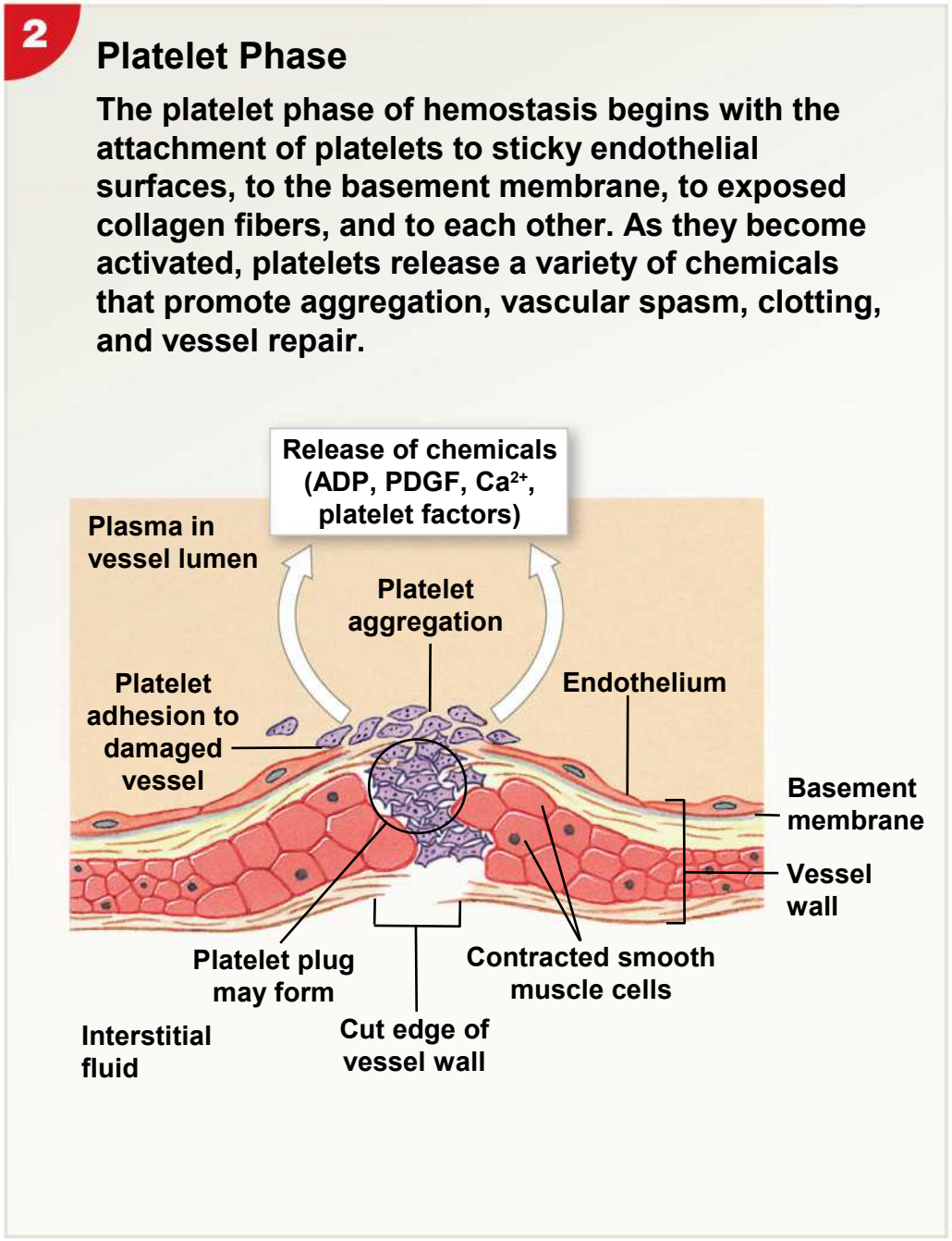
19-7 Hemostasis

- Platelet Phase
  - Activated platelets release clotting compounds
    1. *Adenosine diphosphate (ADP)*
    2. *Thromboxane A_2 and serotonin*
    3. *Clotting factors*
    4. *Platelet-derived growth factor (PDGF)*
    5. Calcium ions

19-7 Hemostasis

- Factors That Limit the Growth of the Platelet Plug
  1. **Prostacyclin,** released by endothelial cells, inhibits platelet aggregation
  2. Inhibitory compounds released by other WBCs
  3. Circulating enzymes break down ADP
  4. Negative (inhibitory) feedback from serotonin
  5. Development of blood clot isolates area

Figure 19-12 The Vascular, Platelet, and Coagulation Phases of Hemostasis and Clot Retraction (Step 2)



19-7 Hemostasis

- The **Coagulation Phase**
  - Begins 30 seconds or more after the injury
  - Blood clotting (**coagulation**)
    - *Cascade* reactions
      - Chain reactions of enzymes and **proenzymes**
      - Form three pathways
      - Convert circulating fibrinogen into insoluble fibrin

19-7 Hemostasis

- **Clotting Factors**
  - Also called **procoagulants**
  - Proteins or ions in plasma
  - Required for normal clotting

Table 19-4 Clotting Factors

Table 19–4 Clotting Factors

Factor	Structure	Name	Source	Concentration in Plasma (μg/mL)	Pathway
I	Protein	Fibrinogen	Liver	2500–3500	Common
II	Protein	Prothrombin	Liver, requires vitamin K	100	Common
III	Lipoprotein	Tissue factor (TF)	Damaged tissue, activated platelets	0	Extrinsic
IV	Ion	Calcium ions	Bone, diet, platelets	100	Entire process
V	Protein	Proaccelerin	Liver, platelets	10	Extrinsic and intrinsic
VI	(No longer used)				
VII	Protein	Proconvertin	Liver, requires vitamin K	0.5	Extrinsic
VIII	Protein factor (AHF)	Antihemophilic	Platelets, endothelial cells	15	Intrinsic
IX	Protein factor	Plasma thromboplastin	Liver, requires vitamin K	3	Intrinsic
X	Protein	Stuart–Prower factor	Liver, requires vitamin K	10	Extrinsic and intrinsic
XI	Protein antecedent (PTA)	Plasma thromboplastin	Liver	<5	Intrinsic
XII	Protein	Hageman factor	Liver	<5	Intrinsic; also activates plasmin
XIII	Protein factor (FSF)	Fibrin-stabilizing	Liver, platelets	20	Stabilizes fibrin, slows fibrinolysis

19-7 Hemostasis

- Three Coagulation Pathways
  1. **Extrinsic pathway**
  2. **Intrinsic pathway**
  3. **Common pathway**

19-7 Hemostasis

- The **Extrinsic Pathway**
  - Begins in the vessel wall
  - Outside bloodstream
  - Damaged cells release **tissue factor (TF)**
  - TF + other compounds = enzyme complex
  - Activates Factor X

19-7 Hemostasis

- The **Intrinsic Pathway**
  - Begins with circulating proenzymes
  - Within bloodstream
  - Activation of enzymes by collagen
  - Platelets release factors (e.g., **PF-3**)
  - Series of reactions activates Factor X

19-7 Hemostasis

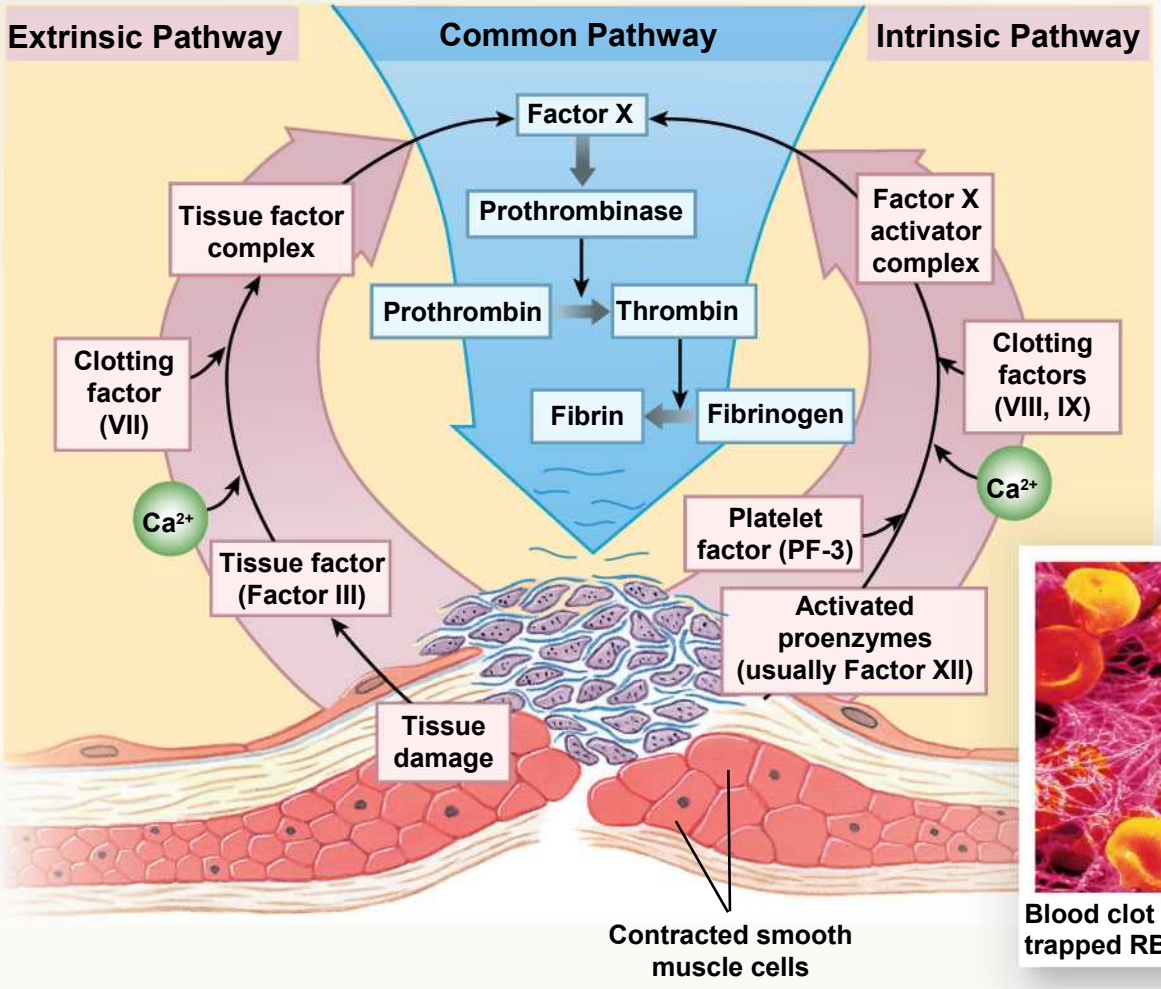
- The **Common Pathway**
  - Where intrinsic and extrinsic pathways converge
  - Forms enzyme **prothrombinase**
  - Converts prothrombin to **thrombin**
  - Thrombin converts fibrinogen to fibrin

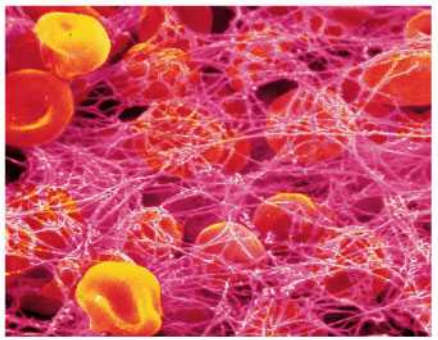
Figure 19-12 The Vascular, Platelet, and Coagulation Phases of Hemostasis and Clot Retraction (Step 3)

3

Coagulation Phase

Coagulation, or blood clotting, involves a complex sequence of steps leading to the conversion of circulating fibrinogen into the insoluble protein fibrin. As the fibrin network grows, blood cells and additional platelets are trapped in the fibrous tangle, forming a blood clot that seals off the damaged portion of the vessel.





Blood clot containing trapped RBCs SEM × 1200

19-7 Hemostasis

- Feedback Control of Blood Clotting
  1. Stimulates formation of tissue factor
  2. Stimulates release of PF-3
     - Forms positive feedback loop (intrinsic and extrinsic)
       - Accelerates clotting

19-7 Hemostasis

- Feedback Control of Blood Clotting
  - **Anticoagulants** (plasma proteins)
    - **Antithrombin-III**
    - Alpha-2-macroglobulin
  - **Heparin**
  - **Aspirin**
  - **Protein C** (activated by **thrombomodulin**)
  - Prostacyclin

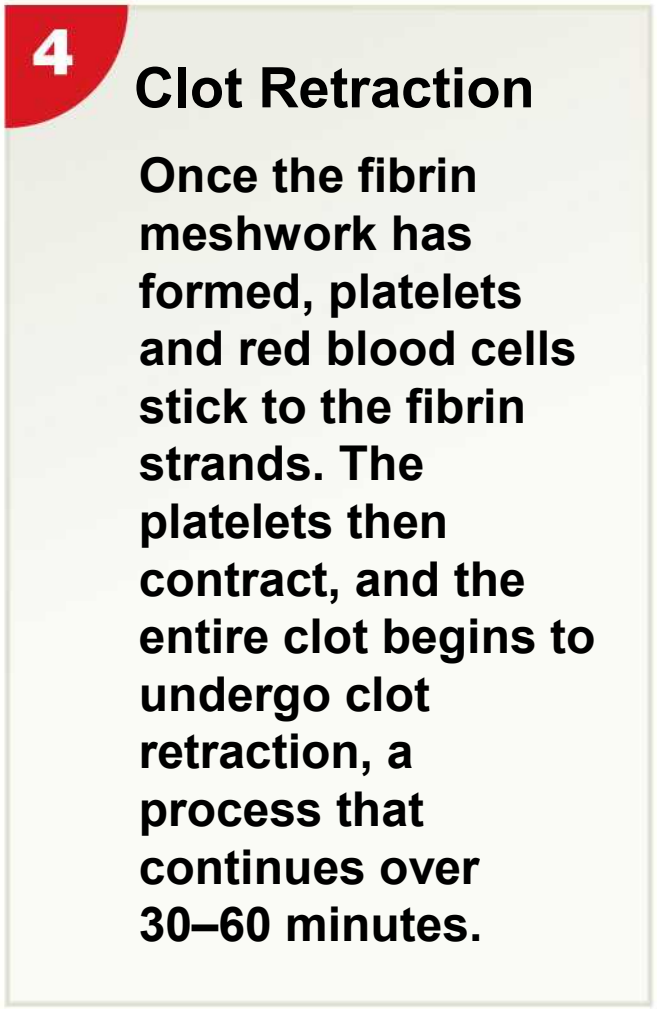
19-7 Hemostasis

- Calcium Ions, Vitamin K, and Blood Clotting
  - Calcium ions (Ca^{2+}) and **vitamin K** are both essential to the clotting process

19-7 Hemostasis

- **Clot Retraction**
  1. Pulls torn edges of vessel closer together
     - Reducing residual bleeding and stabilizing injury site
  1. Reduces size of damaged area
     - Making it easier for fibrocytes, smooth muscle cells, and endothelial cells to complete repairs

Figure 19-12 The Vascular, Platelet, and Coagulation Phases of Hemostasis and Clot Retraction (Step 4)



19-7 Hemostasis

- **Fibrinolysis**
  - Slow process of dissolving clot
    - Thrombin and **tissue plasminogen activator** (t-PA)
      - Activate **plasminogen**
  - Plasminogen produces **plasmin**
    - Digests fibrin strands