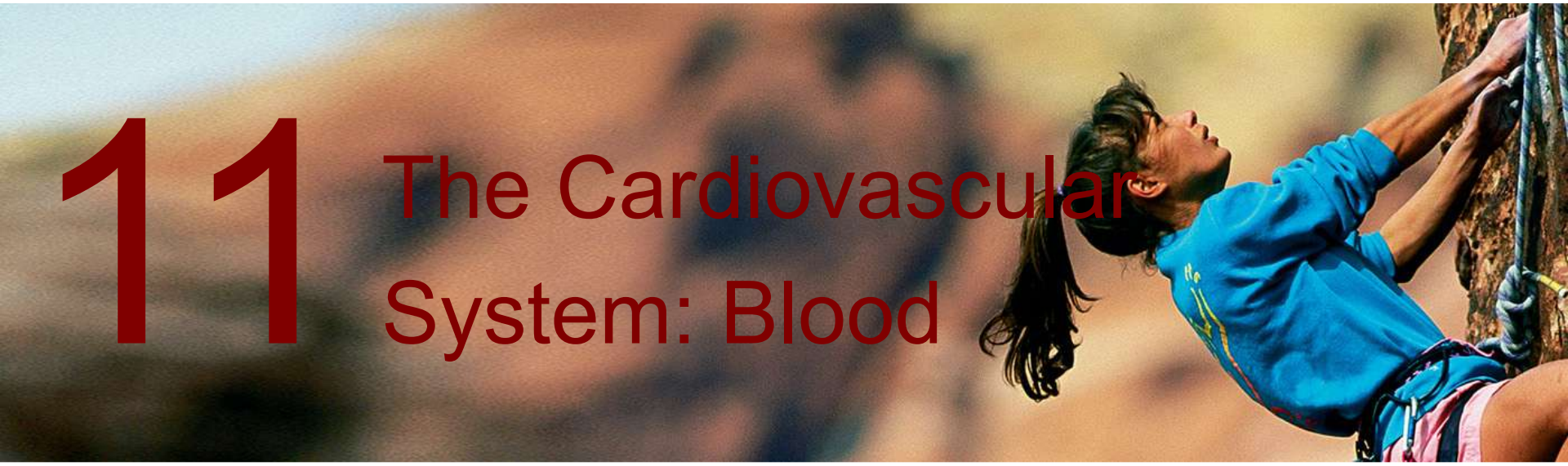


11 The Cardiovascular System: Blood

The Functions of Blood

- Blood Overview:
  - Provides a system for *rapid* transport within the body
    - Nutrients
    - Hormones
    - Waste products
    - Respiratory gases
    - Cells
    - Heat

The Functions of Blood

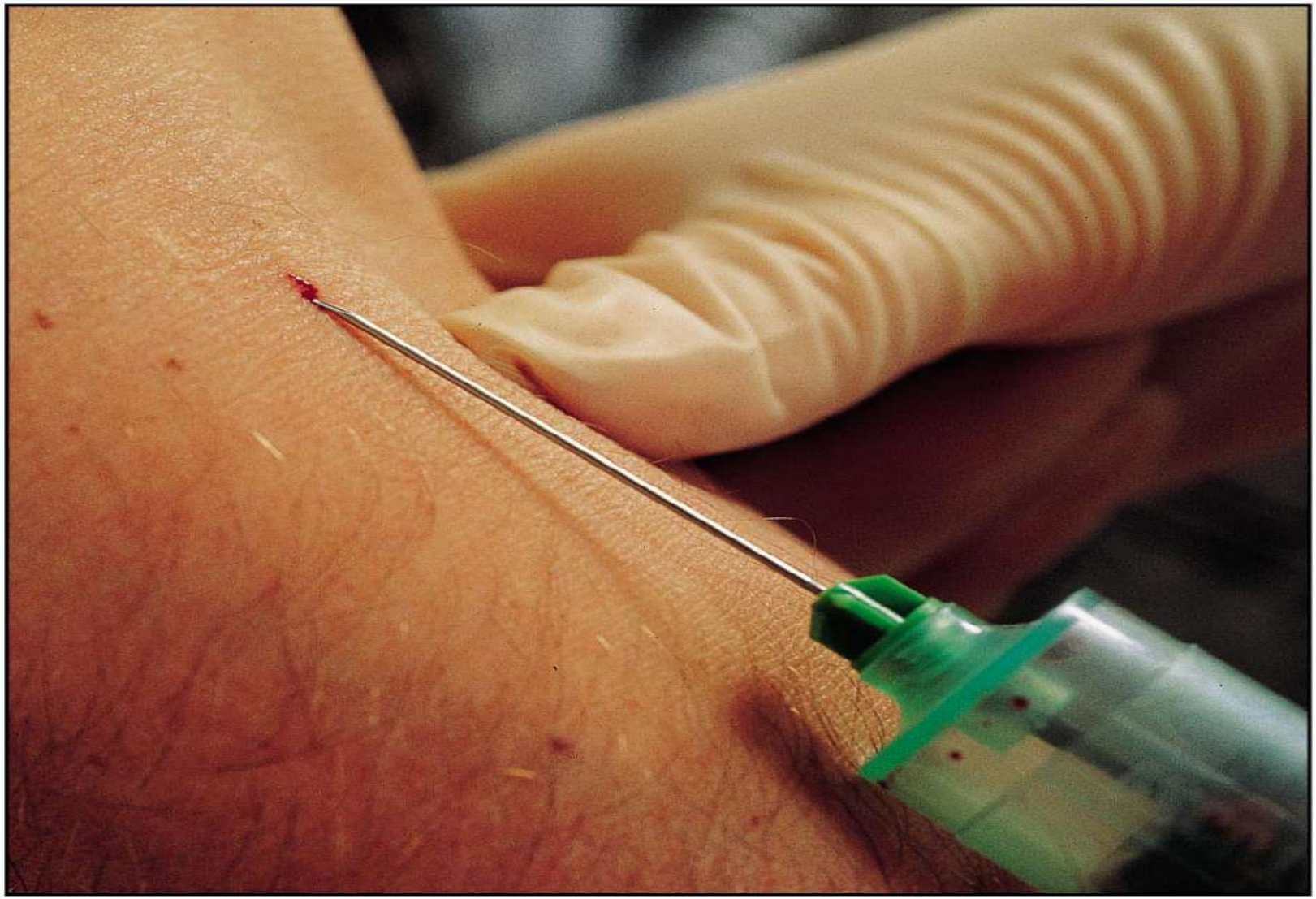
Blood Functions Include:

- Transport of cells and compounds
- Regulate pH and electrolytes of *interstitial fluids*
- Limit blood loss through damaged vessels
- Defend against pathogens, toxins
- Absorb, distribute heat as part of temperature regulation

The Composition of Blood

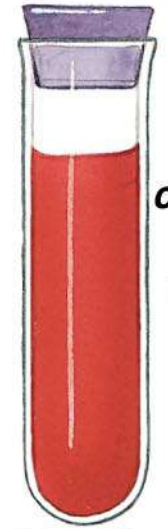
- Blood Collection and Analysis
  - Whole blood can be *fractionated* into:
    - *Plasma* (liquid component)
    - *Formed elements* (cellular components)
      - Red blood cells (RBCs)
      - White blood cells (WBCs)
      - Platelets

Blood Sample



(a) Taking a blood sample

The Composition of Whole Blood



Sample of whole blood

consists of

Plasma (55%)

PLASMA COMPOSITION

Plasma proteins	7%
Other solutes	1%
Water	92%

Transports organic and inorganic molecules, formed elements, and heat

(b) Components of plasma

PLASMA PROTEINS

Albumins (60%)	Major contributors to osmotic pressure of plasma; transport lipids, steroid hormones
Globulins (35%)	Transport ions, hormones, lipids; immune function
Fibrinogen (4%)	Essential component of clotting system; can be converted to insoluble fibrin
Regulatory proteins (<1%)	Enzymes, proenzymes, hormones

OTHER SOLUTES

Electrolytes	Normal extracellular fluid ion composition essential for vital cellular activities. Examples: Na^+, K^+, Ca^{2+}, Cl^-, HCO_3^-
Organic nutrients	Used for ATP production, growth, and maintenance of cells. Examples: Fatty acids, glucose, amino acids
Organic wastes	Carried to sites of breakdown or excretion. Examples: Urea, bilirubin

Blood Plasma

Plasma Basics

- Makes up about 55% of whole blood
- *Water* makes up about 92% of plasma
- Has more protein and oxygen than interstitial fluid
- Plasma proteins fall in three classes
  - *Albumins*
  - *Globulins*
  - *Fibrinogen*

Formed Elements

Hemopoiesis—The cellular pathways by which the formed elements are produced.

Stem cells (*hemocytoblasts*)—Cells that divide and mature to produce all three classes of formed elements.

Blood Plasma

Key Note:

Approximately half the volume of whole blood consists of cells and cell products (the *formed elements*). Plasma resembles interstitial fluid but contains a unique mixture of proteins not found in other extracellular fluids.

Formed Elements

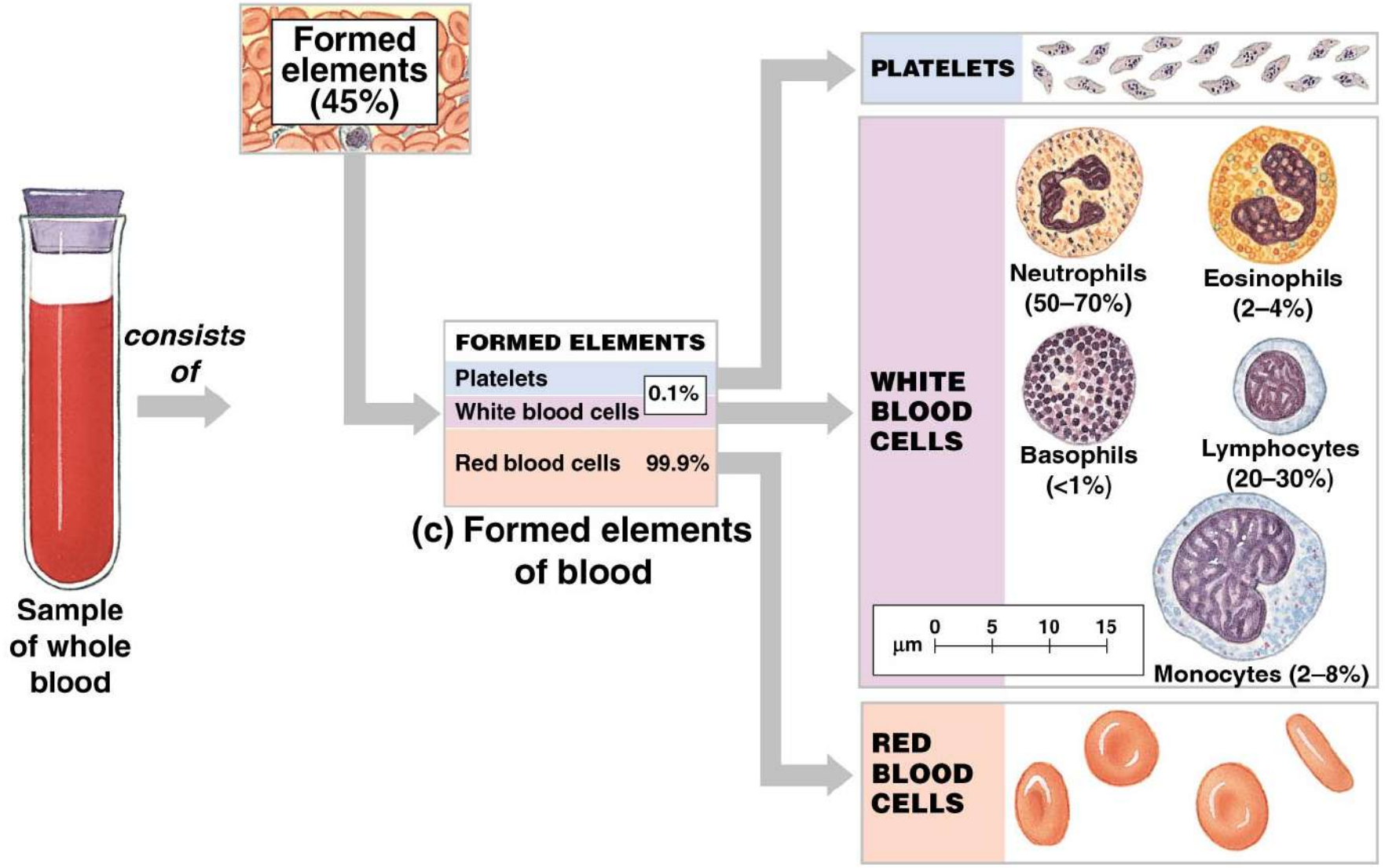
Red Blood Cells:

- Also called, *erythrocytes* or *RBCs*
- Make up about 45% of whole blood volume
- Make up 99.9% of the formed elements

Formed Elements

Hematocrit—Percentage of whole blood volume taken up by formed elements (mostly RBCs). In clinical shorthand, it's called, the "*crit.*"

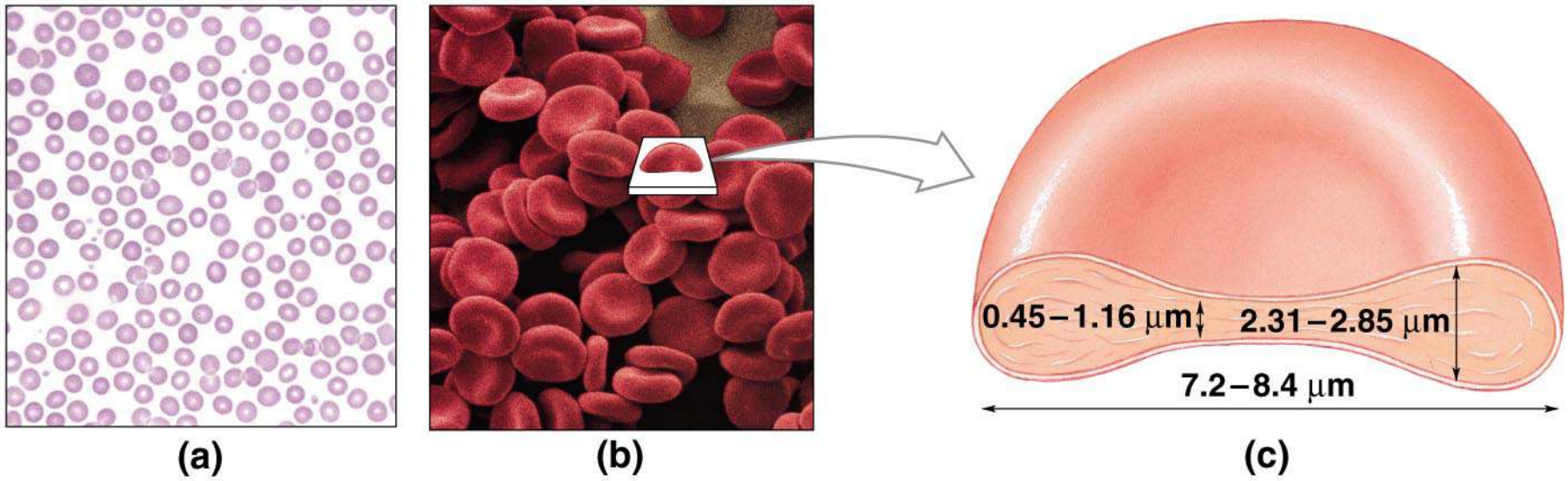
Formed Elements



Formed Elements

- Properties of RBCs
  - Transport oxygen and carbon dioxide in blood stream
  - Have large surface to volume ratio
    - Speeds up gas loading/unloading
  - Lack most organelles
    - Makes more room for *hemoglobin*
  - Degenerate after about 120 days

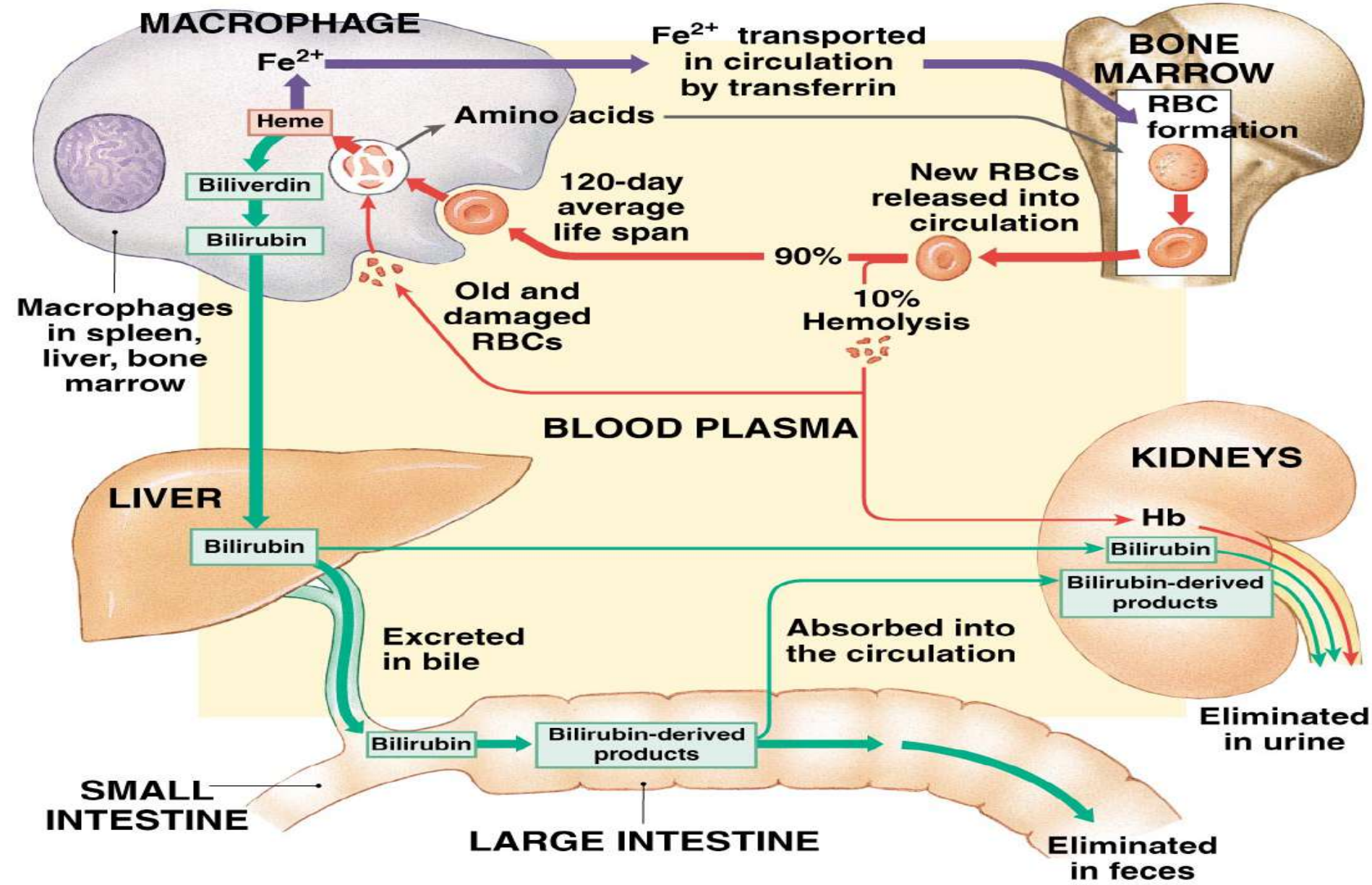
The Anatomy of Red Blood Cells



Formed Elements

- Red Blood Cell Composition:
  - *Hemoglobin* makes up 95% of RBC protein
  - Globular protein composed of four *subunits*
    - Each subunit contains:
      - A *globin* protein chain
      - A molecule of *heme*
      - An atom of *iron*
      - A binding site for one oxygen molecule
  - *Phagocytes* recycle hemoglobin from damaged or dead RBCs

Hemoglobin Recycling

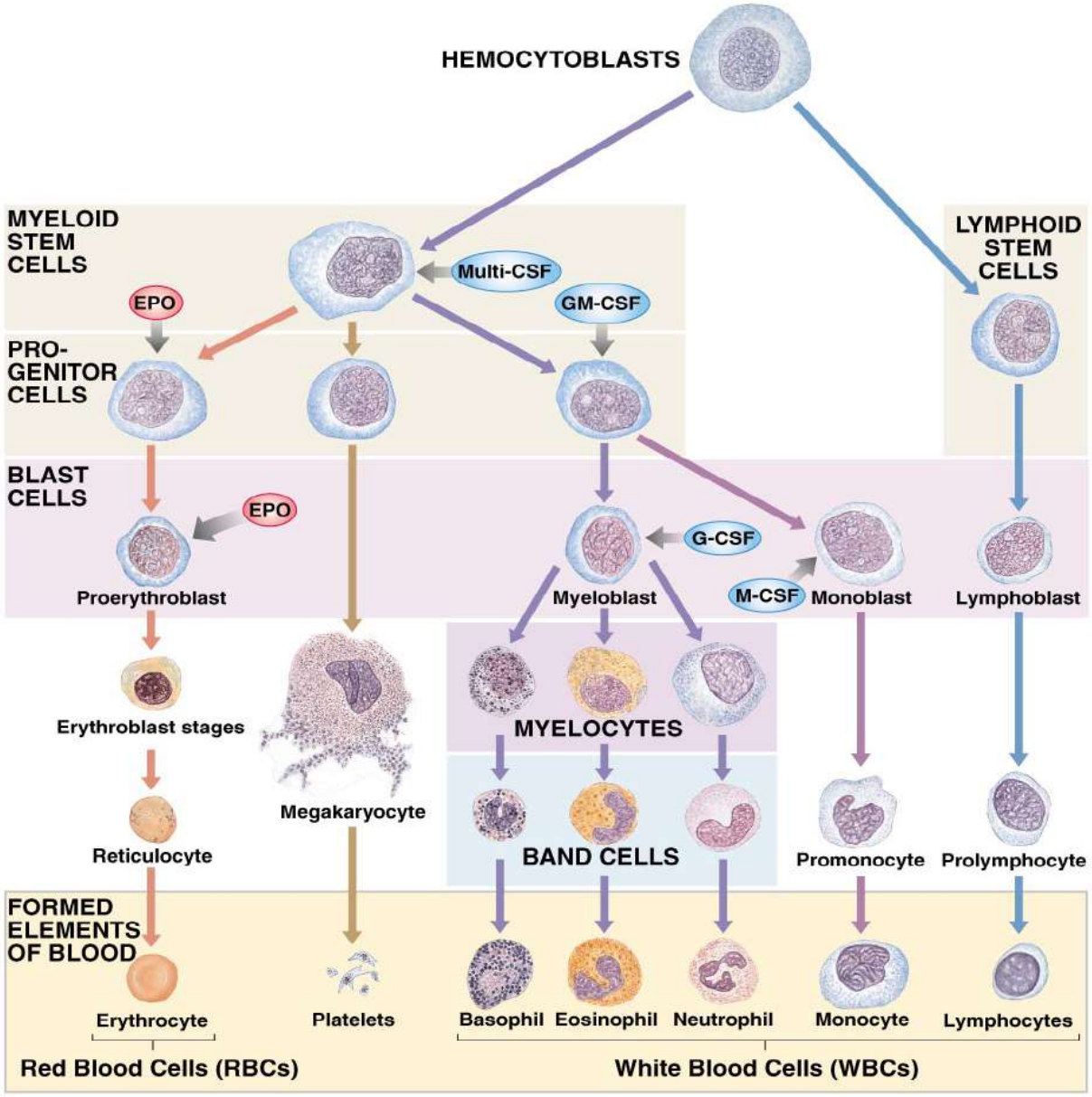


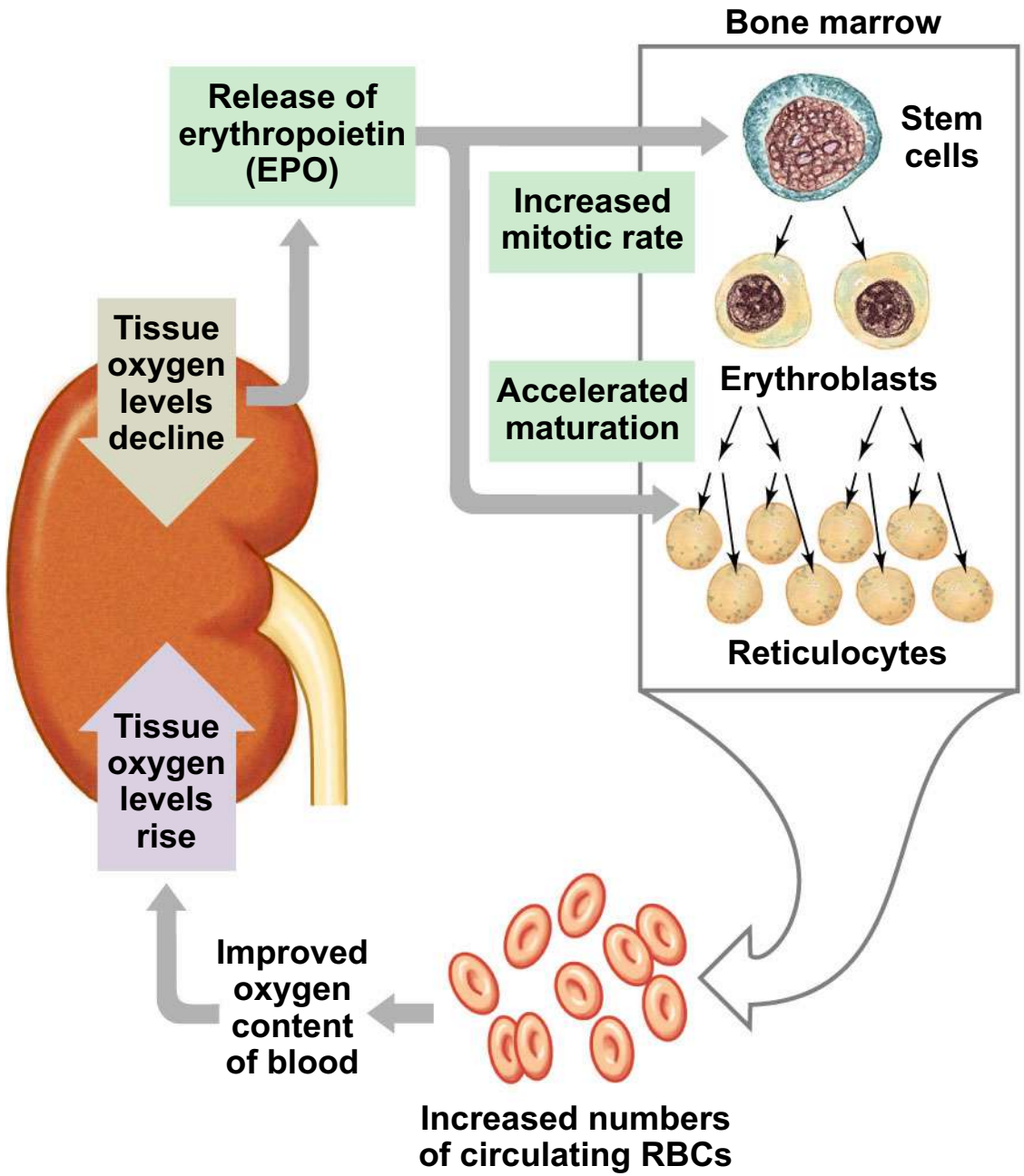
Formed Elements

Erythropoiesis—Process for formation of red blood cells

- Occurs mainly in the bone marrow
- Stimulated by *erythropoietin* (*EPO*)
  - *EPO* increases when oxygen levels are low
- Development stages include:
  - *Erythroblasts*
  - *Reticulocytes* (after nucleus is expelled)

Differentiation of RBCs, Platelets, and WBCs





Formed Elements

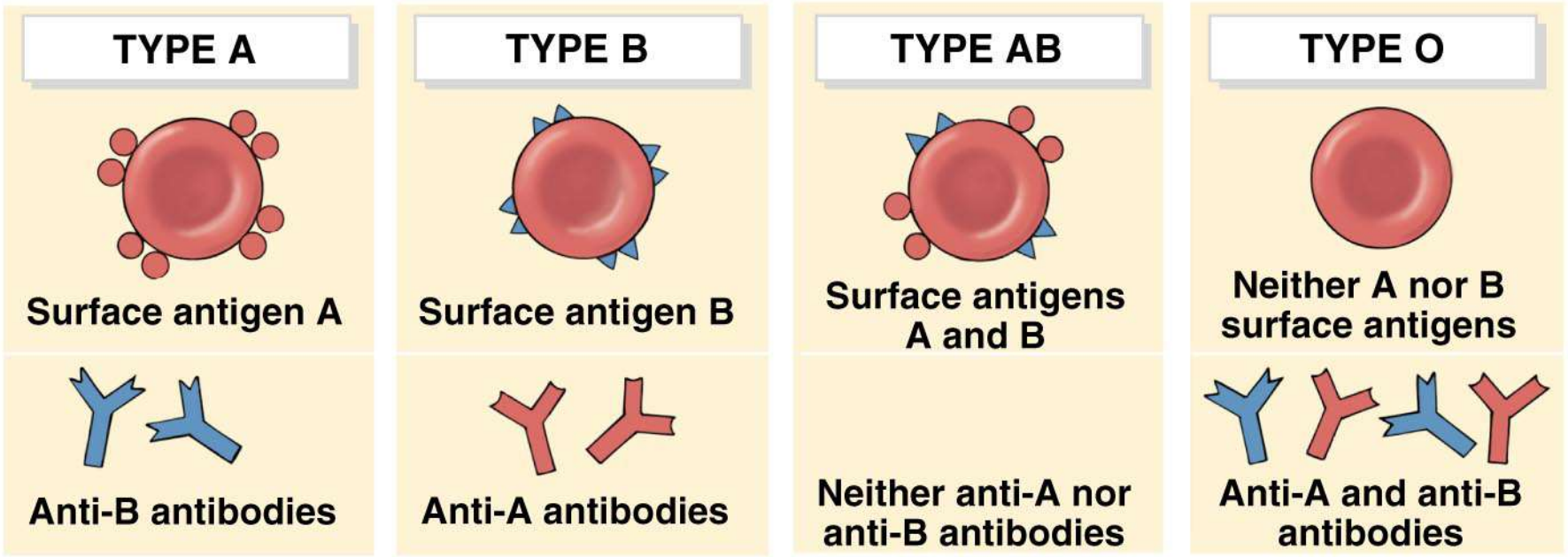
Key Note:

Red blood cells (RBCs) are the most numerous cells in the body. They circulate for about four months before being recycled; millions are produced each *second*. The hemoglobin inside transports oxygen from the lungs to peripheral tissues and carbon dioxide from the tissues to the lungs.

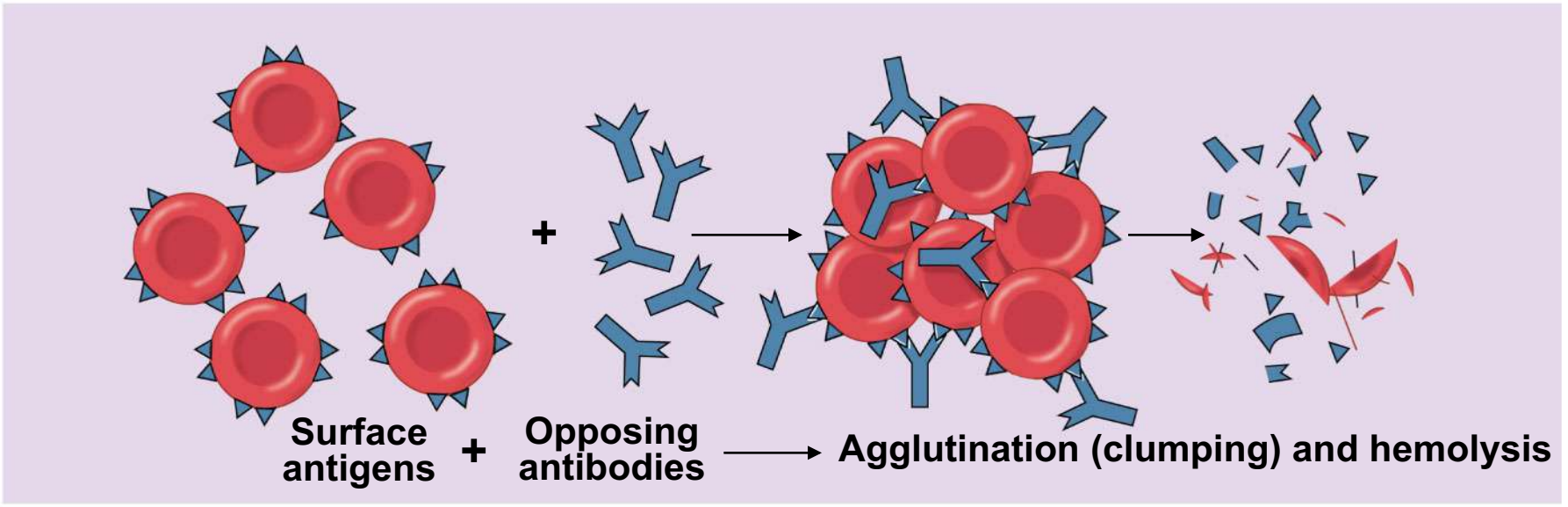
Formed Elements

- Blood Type
  - Determined by presence or absence of specific *antigens* (*agglutinogens*) on outside *surface* of RBC
  - Antigens are called *A*, *B*, and *Rh*
  - *Antibodies* (*agglutinins*) in plasma react with *foreign* antigens on RBCs
    - RBCs clump and break open
  - Anti-Rh antibody made after exposure to Rh-positive blood cells

Blood Types and Cross-Reactions



(a)


Surface antigens
+
Opposing antibodies
Agglutination (clumping) and hemolysis

Formed Elements

- White Blood Cells (WBCs)
  - Also called, *leukocytes*
  - Defend the body against:
    - Pathogens
    - Toxins
    - Abnormal cells
    - Damaged cells

Formed Elements

WBC Properties

- Perform *diapedesis*—Push between cells to cross blood vessel walls and enter the tissues
- Exhibit *chemotaxis*—Move toward specific chemicals released by bacteria or injured cells
- Consist of two groups:
  - *Granulocytes* (cytoplasmic granules)
  - *Agranulocytes* (no granules)

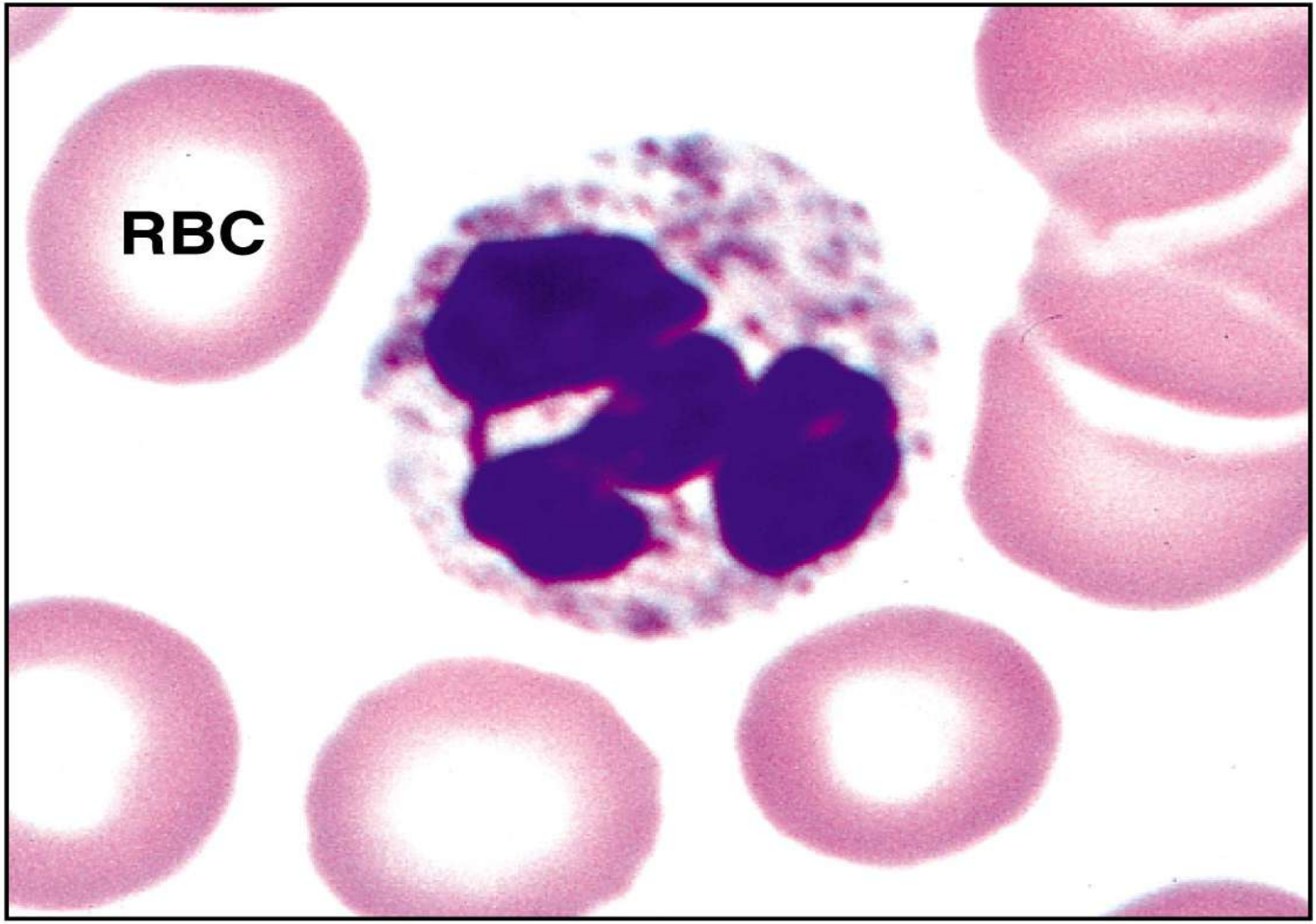
Formed Elements

- Three Types of *Granulocytes*
  - *Neutrophils*
    - *50–70%* of circulating WBCs
    - *Phagocytic*
  - *Eosinophils*
    - Less common
    - *Phagocytic*
    - Attracted to foreign proteins
  - *Basophils*
    - Release *histamine*
    - Promote *inflammation*

Formed Elements

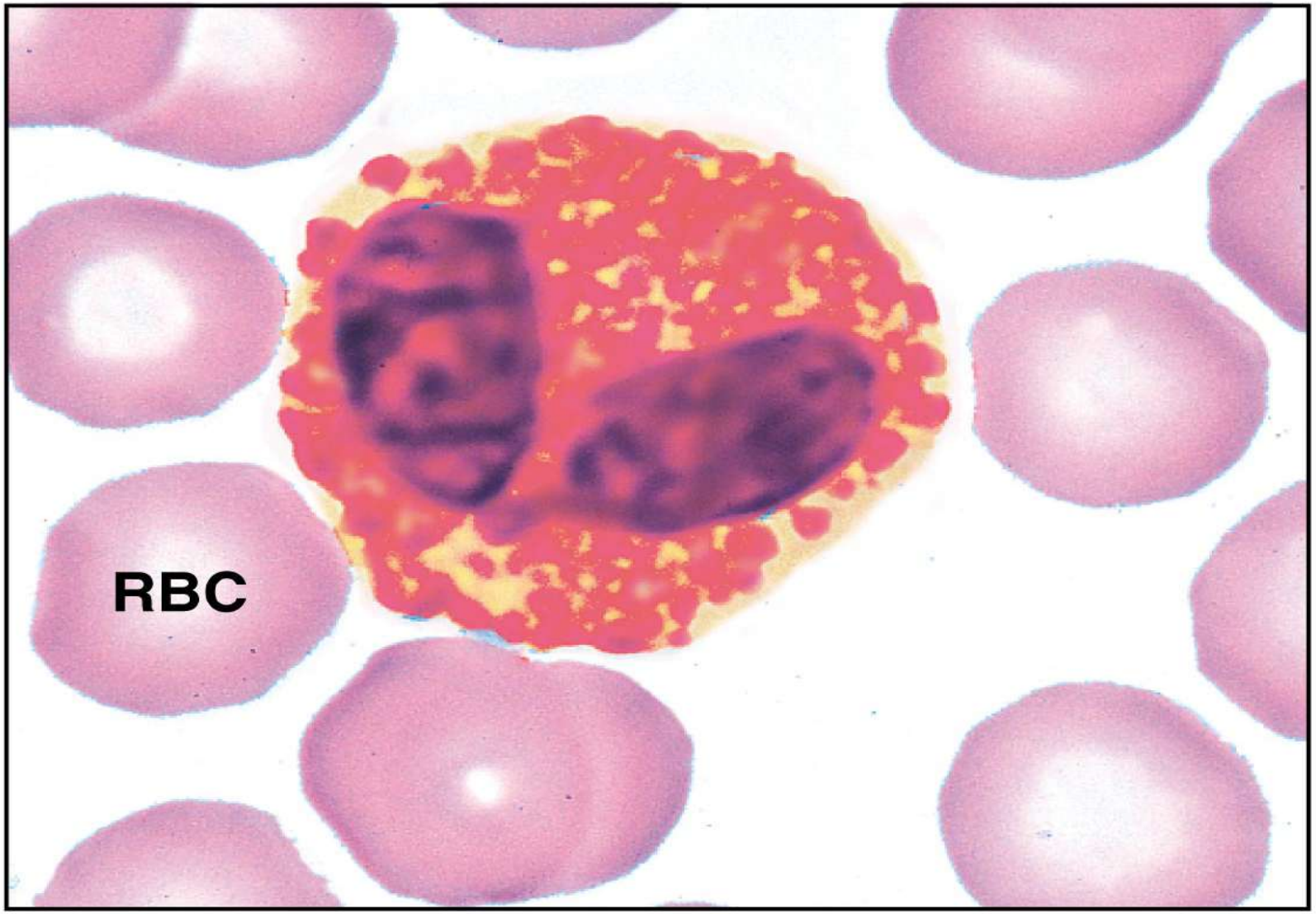
- Two Types of *Agranulocytes*
  - *Lymphocytes*
    - Found mostly in *lymphatic system*
    - Provide *specific* defenses
      - Attack foreign cells
      - Produce *antibodies*
      - Destroy abnormal (cancer) cells
  - *Monocytes*
    - Migrate into tissues
    - Become *macrophages*
    - Live as *phagocytic amoeba*

White Blood Cells



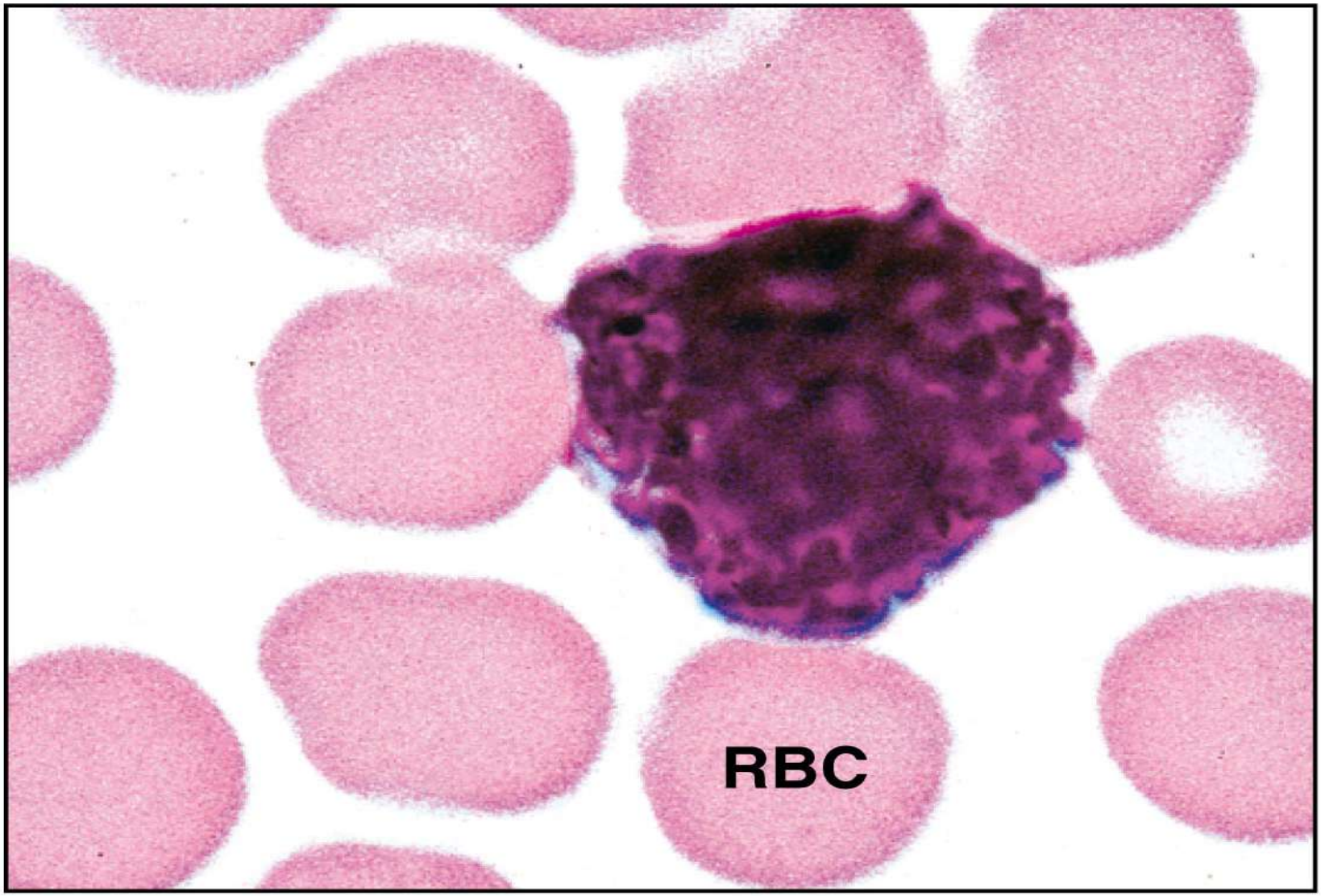
(a) Neutrophil

White Blood Cells



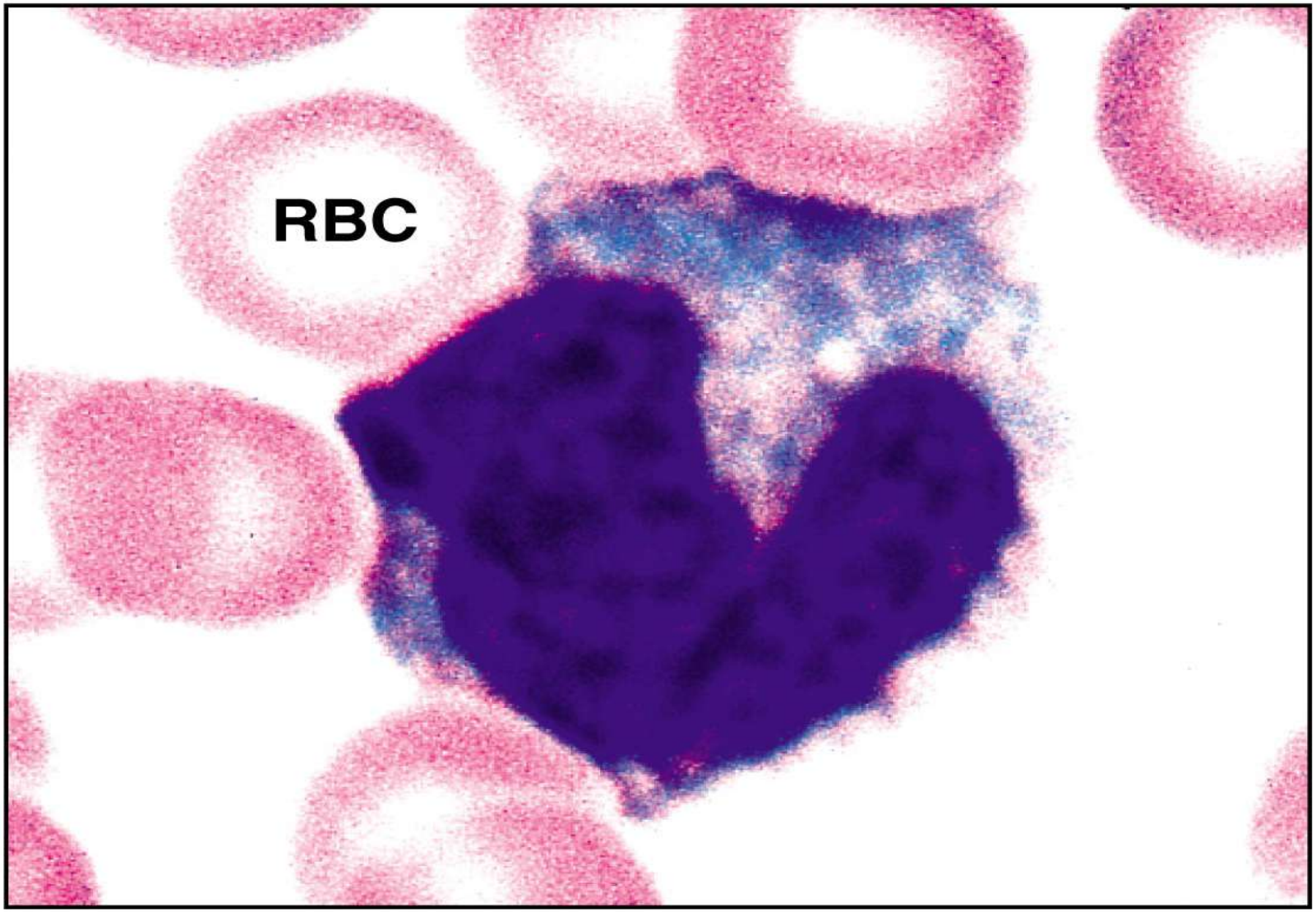
(b) Eosinophil

White Blood Cells



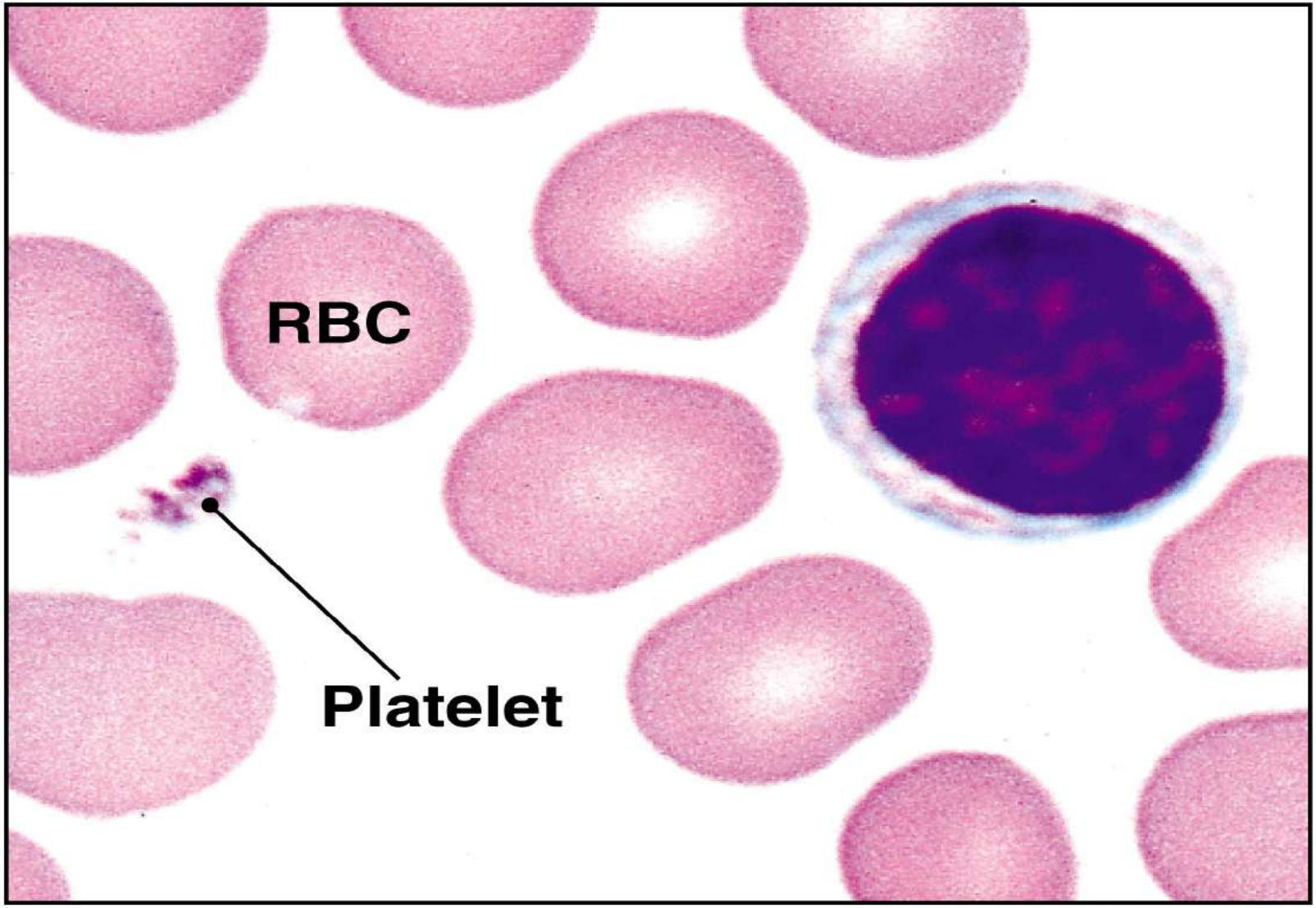
(c) Basophil

White Blood Cells



(d) Monocyte

White Blood Cells



(e) Lymphocyte

Formed Elements

Production of WBCs in Bone Marrow

- *Myeloid stem cells* produce:
  - Granulocytes (three types)
  - Monocytes (future macrophages)
- *Lymphoid stem cells* produce lymphocytes
  - Process called, *lymphopoiesis*
  - Lymphocytes enter blood
  - Migrate to lymphoid tissues

Formed Elements

- Regulation of WBC Maturation
  - *Colony-stimulating factors* (CSFs)—Hormones which regulate certain WBC populations
    - Four CSFs are known
    - CSFs target *stem cell lines*
    - Several CSFs used with cancer patients with bone marrow suppression

Formed Elements

- Regulation of WBC Maturation
  - Regulation of lymphocyte maturation is poorly understood
    - *Thymosins* (hormones in *thymus* gland) trigger *T cells* to develop

Formed Elements

Key Note:

RBCs outnumber WBCs by a 1000 to 1. WBCs defend the body against infection, foreign cells, or toxins, and assist in the repair of damaged tissues. Most numerous are neutrophils, which engulf bacteria, and lymphocytes, which are responsible for the specific immune defenses.

Platelets

Platelets:

- Produced in the bone marrow
- Released from *megakaryocytes* as cytoplasmic fragments into the blood
- Essential to clotting process

Hemostasis

Hemostasis—Processes that stop the loss of blood from a damaged vessel. Largely dependent on platelets and soluble proteins (clotting factors).

Hemostasis

Three phases in Hemostasis:

- *Vascular phase*
  - Local contraction of injured vessel
- *Platelet phase*
  - Platelets stick to damaged vessel wall
- *Coagulation phase*
  - *Clotting factors* in plasma form *blood clot*

Hemostasis

The Clotting Process

- *Coagulation* pathways require an external trigger
  - *Extrinsic pathway*
    - Triggered by factors released by injured endothelial cells or peripheral tissues
  - *Intrinsic pathway*
    - Triggered by factors released by platelets stuck to vessel wall
  - Both pathways lead to *common pathway*
    - *Thrombin* converts soluble *fibrinogen* subunits to an insoluble polymer, *fibrin*

Hemostasis

The Structure of a Blood Clot

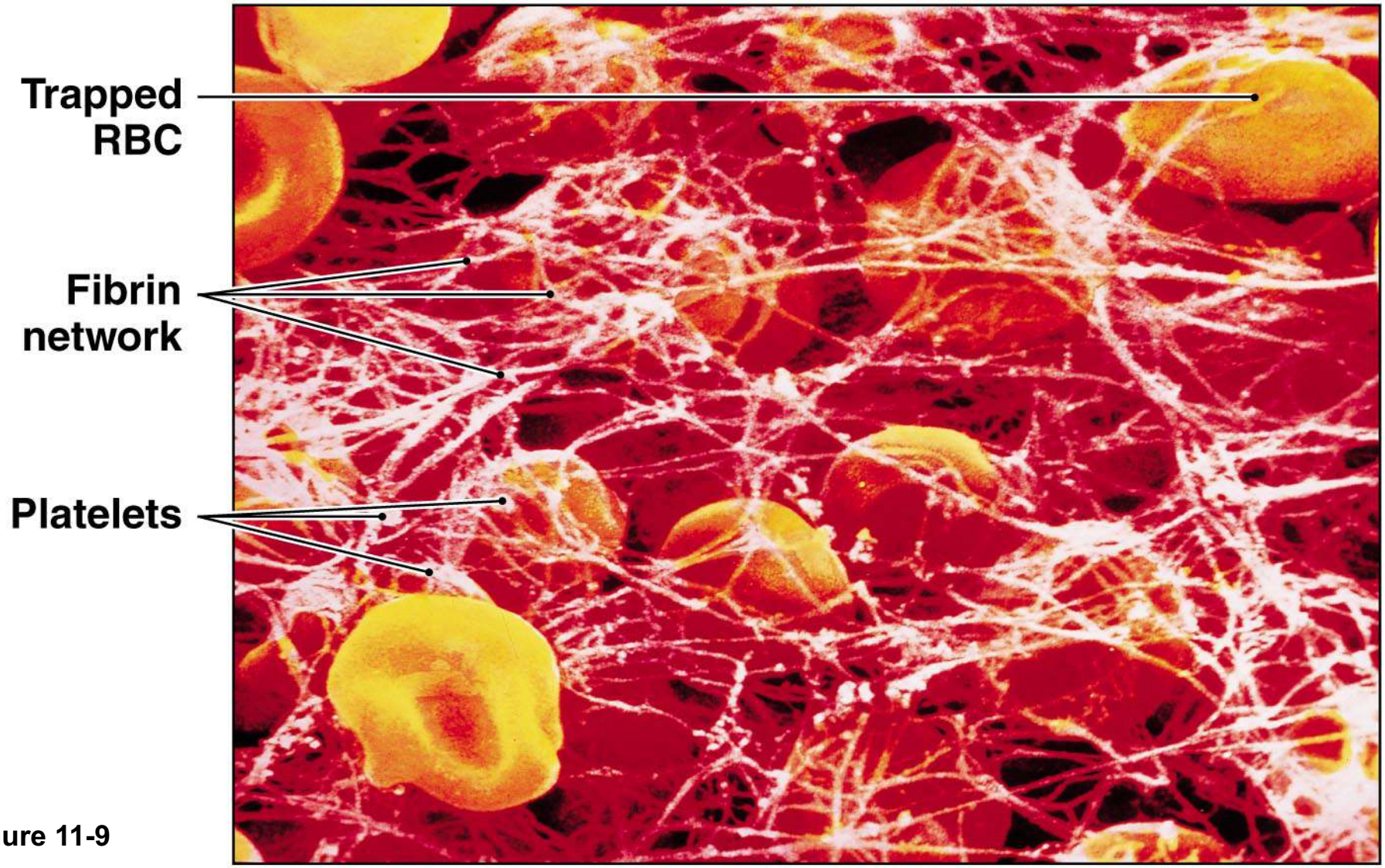
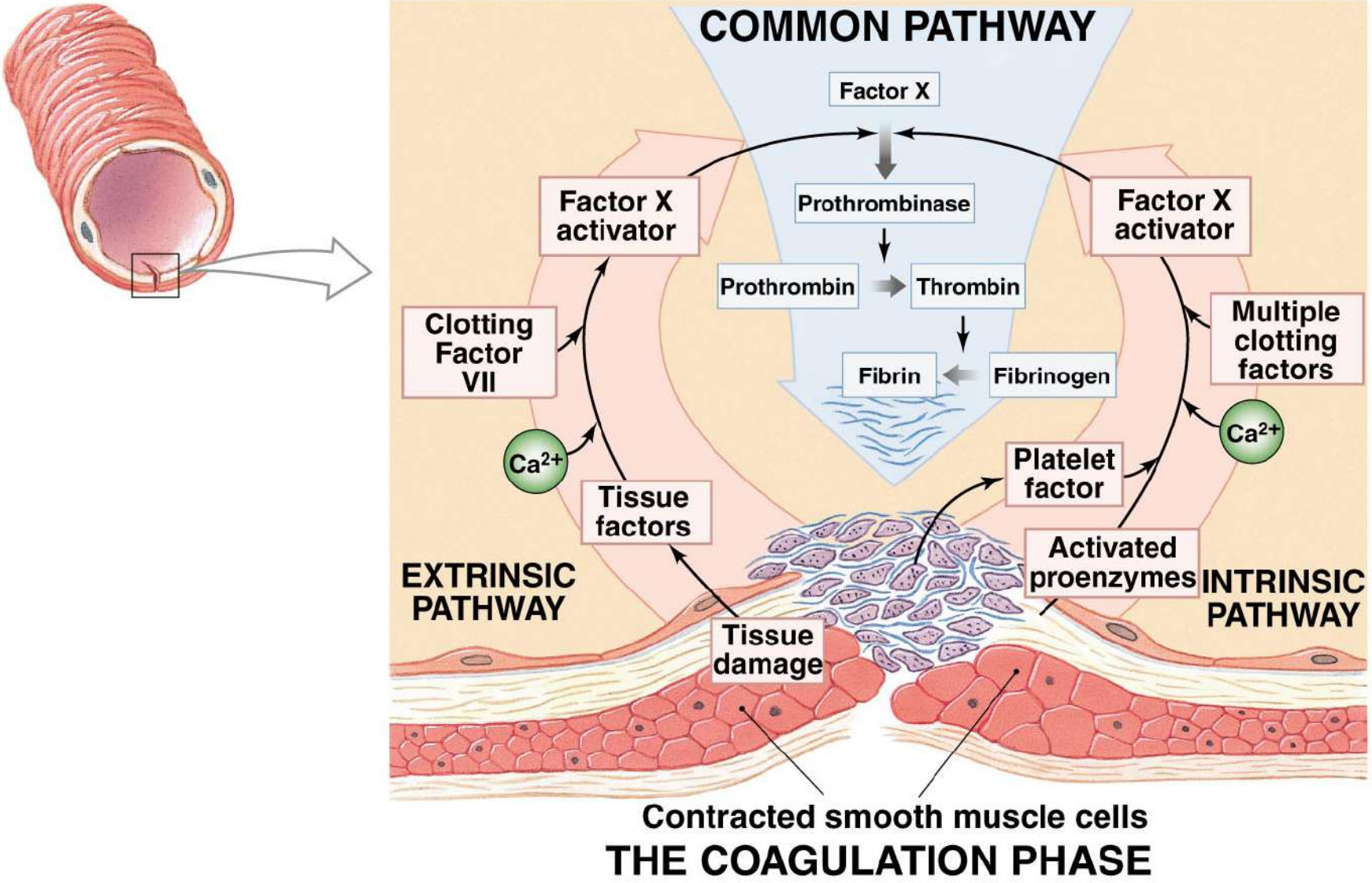


Figure 11-9

Coagulation Phase of Hemostasis



Hemostasis

Clot Retraction and Removal

- Clot *retracts* because platelets *contract*
  - Pulls broken vessel closed
- Clot gradually dissolves
  - Called, *fibrinolysis*
  - *Plasmin*, an enzyme derived from *plasminogen* in the plasma, cuts *fibrin* apart like a molecular scissors

Hemostasis

Key Note:

Platelets coordinate hemostasis (blood clotting). If they are activated by abnormal changes in their surroundings, platelets release clotting factors and other chemicals. Hemostasis is a complex cascade that produces a fibrous patch that is subsequently remodeled and then removed as repair proceeds.