

# The Cardiovascular System: Blood

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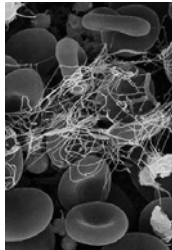
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## The Functions of Blood – General Overview

- Provides a system for *rapid* transport within the body
  - Nutrients
  - Hormones
  - Waste products
  - Respiratory gases
  - Cells & Blood Components
  - Heat
- Regulation
  - pH
- Protection
  - Limit blood loss through damaged vessels hemostasis
  - Defend against pathogens, toxins
- Thermoregulation
  - Absorb, distribute heat as part of temperature regulation



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## The Composition of Blood

- Whole blood can be *fractionated* into:
  - Plasma* (liquid component)
    - Approximately 55% of blood volume
  - Formed elements* (cellular components)
    - Red blood cells (RBCs)
    - White blood cells (WBCs)
    - Platelets (thrombocytes)
    - Approximately 45% of blood volume
      - Slight differences between males and females

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## The Composition of 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*

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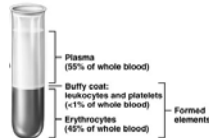
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## The Composition of Whole Blood - Formed Elements

- *Formation of 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.
- **Formed Elements**
  - Red Blood Cells
    - Also called, *erythrocytes* or *RBCs*
    - Make up about 45% of whole blood vol.
    - Make up 99.9% of the formed elements
  - *Hematocrit*—Percentage of whole blood volume taken up by formed elements (mostly RBCs). In clinical shorthand, it's called, the "*crit.*"




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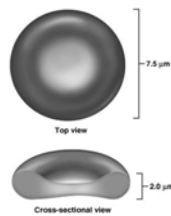
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## The Formed Elements – RBC's

- Properties & Functions 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
  - Bi-concave shape
  - Approximately 8 micrometers in diameter
  - No organelles in mature RBC (only in developing cells)




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## The Formed Elements – RBC's

- 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




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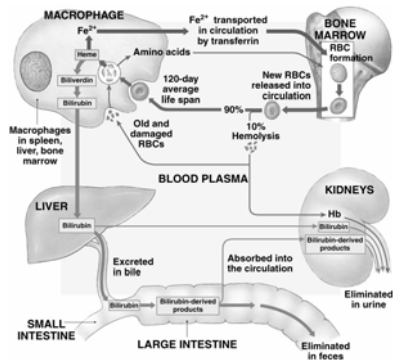
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## The Formed Elements – RBC's

- Hemoglobin Recycling




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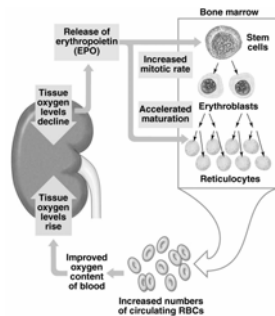
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## The Formed Elements – RBC's

- 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)




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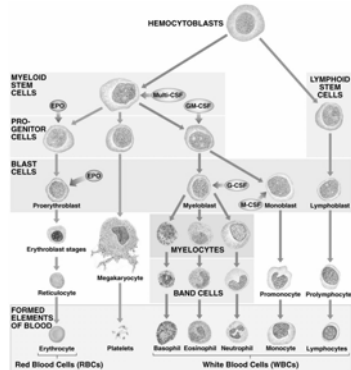
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## The Formed Elements - Origins

### ■ Hematopoiesis

- The formation of blood cells
- Starting point:
  - Hemocytoblast
    - an undifferentiated stem cell




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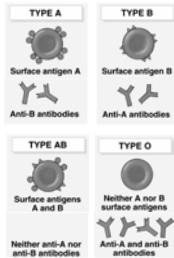
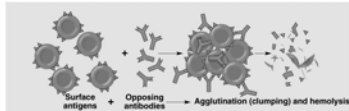
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## Blood Type

- Determined by presence or absence of specific *antigens* on outside *surface* of RBC
  - *Antigens (agglutinogens)* are called *A, B, and Rh*
  - *Antibodies (agglutinins)* in plasma react with *foreign antigens* on RBCs and are called *anti-A, anti-B,...*
    - Cause the RBCs clump and break open



- Anti-Rh antibody made after exposure to Rh-positive blood cells – implications?

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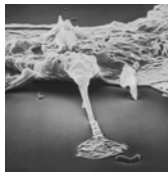
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## The Formed Elements – WBCs

- White Blood Cells (WBCs) or *leukocytes*
- Defend the body against:
  - Pathogens
  - Toxins
  - Abnormal cells
  - Damaged cells
- 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
- WBC belong to one of two groups:
  - *Granulocytes* (cytoplasmic granules)
  - *Agranulocytes* (no granules)




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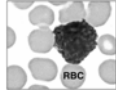
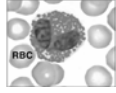
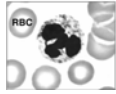
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## The Formed Elements – Granulocytes

### Three Types of Granulocytes

- **Neutrophils**
  - 50–70% of circulating WBCs
  - Phagocytic
- **Eosinophils**
  - Less common
  - Phagocytic
  - Attracted to foreign proteins
- **Basophils**
  - Rare (less than .1%)
  - Release *histamine*
  - Promote *inflammation*




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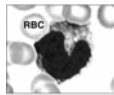
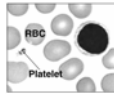
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## The Formed Elements – Agranulocytes

### 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*




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## The Formed Elements – WBC Production & Maturation

- Production of WBCs takes place in bone marrow (red)
- **Differentiation of the hemocytoblast produces**
  - **Myeloid stem cells** which produce:
    - Granulocytes (three types)
    - Monocytes (future macrophages)
  - **Lymphoid stem cells** which produce lymphocytes
    - Process called, *lymphopoiesis*
    - Lymphocytes enter blood
    - Migrate to lymphoid tissues
- Regulation of WBC production and 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
  - Regulation of lymphocyte maturation is poorly understood
    - *Thymosins* (hormones in *thymus gland*) trigger *T cells* to develop

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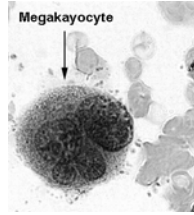
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## The Formed Elements - Platelets

- Platelets (thrombocytes) are
  - Produced in the bone marrow
  - Released from *megakaryocytes* as cytoplasmic fragments into the blood
  - Essential to clotting process
    - Contain clotting factors




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## The clotting process - hemostasis

- Processes that stop the loss of blood from a damaged vessel.
  - Largely dependent on platelets and soluble proteins (clotting factors).
- Three phases in Hemostasis:
  - *Vascular phase*
    - Local contraction of injured vessel
  - *Platelet phase*
    - Platelets stick to damaged vessel wall and become activated
  - *Coagulation phase*
    - Clotting factors in plasma form *blood clot*

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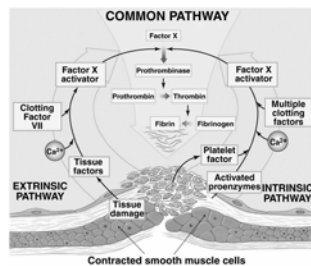
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## The Coagulation Phase

- *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*




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## Hemostasis – The end...

What needs to happen to the clot?

- 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

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