

CHAPTER 14: CARDIOVASCULAR SYSTEM: BLOOD

OBJECTIVES:

1. Describe blood according to its tissue type and major functions.
2. Define the term *hematology*.
3. Name the average volume of blood in a human.
4. Name the two major components of blood and the percentage of each by weight.
5. Describe the three types of blood cells in terms of their circulating concentration, overall function, and key characteristics.
6. Explain why a mature erythrocyte lacks a nucleus.
7. Explain why red blood cells have a relatively short life span.
8. Discuss where erythropoiesis occurs in adults and fetuses, and what other factors are needed for red cell production.
9. Outline the negative feedback loop involving the hormone erythropoietin.
10. Explain why the solid portion of blood, formed elements, packed cell volume, or hematocrit are all composed of approximately 99% erythrocytes.
11. Distinguish between granulocytes and agranulocytes, name the leukocytes in each category, and list the specific function for each cell type.
12. Name the process by which a leukocyte leaves the blood stream and enters a tissue (Is this normal?).
13. Name the primitive bone marrow cell from which all blood cells arise.
14. List the components transported in blood plasma.
15. Outline and explain the three steps involved in hemostasis.

CHAPTER 14: CARDIOVASCULAR SYSTEM: BLOOD

Objectives (continued)

16. Name the hormone that platelets within a platelet plug release that causes further vasoconstriction of a vessel.
17. Describe the final step in blood coagulation.
18. Name the natural anticoagulant released by basophils and mast cells.
19. Define the term *agglutination*.
20. Discuss blood typing (A, B, AB, O) and transfusions in terms of the following:
 - a. the antigen present on a person's (recipient's) erythrocytes;
 - b. the antibodies within the person's (recipient's) plasma;
 - c. compatible donor types;
 - d. incompatible donor types.
21. Identify the blood type considered the universal donor and the blood type considered the universal recipient.
22. Discuss what is meant by Rh incompatibility and its consequences.

CHAPTER 14: CARDIOVASCULAR SYSTEM: BLOOD

I. Introduction

Blood is a **connective tissue** whose cells are suspended in liquid called plasma.

Functions of blood include **transporting substances** between body cells and the outside, maintaining **homeostasis** and protection.

Hematology is the study of blood, blood-forming tissues and the disorders that affect them.

II. BLOOD VOLUME AND COMPOSITION:

A. Blood volume varies from individual to individual, but the **average volume** (70 kg male) is **5 liters**.

B. Blood can be separated into **two major components**:

See Fig 14.1, page 521.

1. **Solid cells** or "**formed elements**" (**45%**) which is composed mainly of red blood cells.

a. Quantitation of this portion of blood represents the **hematocrit (HCT)** reading or **packed cell volume (PCV)**. See Fig 14.2, page 522.

2. **Liquid plasma (55%)** which contains water, electrolytes, hormones, wastes, proteins and much more.

III. BLOOD CELLS or "Formed Elements":

Blood is composed of **three types** of cells, including red blood cells, white blood cells, and platelets.

See Fig 14.1, page 521.

CHAPTER 14: CARDIOVASCULAR SYSTEM: BLOOD

III. Blood Cells (continued)

A. Red Blood Cells (RBC) = Erythrocytes:

See Fig 14.4, page 524.

1. tiny, biconcave disks (increase SA);
2. contain **hemoglobin** which is loosely bound to oxygen. See Fig 14.5, page 525.
 - a. oxyhemoglobin = bright red;
 - b. Hb = protein + iron;
3. Mature cells **lack nuclei** (more room for Hb);
4. RBC Count (RCC) = the number of rbc's/mm³ blood.
 - a. Average RCC = **4-6 million rbc's/mm³**;
5. Average life-span = **120 days**
 - a. macrophages destroy worn rbc's,
 - b. iron in Hb is recycled,
 - c. See Table 14.1, page 525 and Fig 14.7, page 528.
6. Production (Erythropoiesis)
 - a. In fetuses = yolk sac, liver, spleen;
 - b. in adults = **red bone marrow**;
 - c. B₁₂, folic acid, and iron are all needed.
7. Number normally remains stable.
 - a. Negative feedback mechanism involving the hormone **erythropoietin** produced and secreted by the special cells in the kidney; Target?
 - b. See Fig 14.6, page 526.
 - m low O₂ levels = erythropoietin release = stimulation of rbc production;
8. compose 99% of blood cells.

CHAPTER 14: CARDIOVASCULAR SYSTEM: BLOOD

III. Blood Cells (continued)

B. White Blood Cells (WBC) = Leukocytes

1. 5 types composed of: See Fig 14.9-14.13, page 530.
 - a. **granulocytes**
 - m neutrophils
 - m eosinophils
 - m basophils;
 - b. **agranulocytes**
 - m monocytes
 - m lymphocytes;
2. **function to control disease:**
 - a. **neutrophils**
 - m most abundant WBC = 54%-62%;
 - m polymorphonucleocytes (**PMN**);
 - m **phagocytosis** of foreign particles (disease organisms & debris;
 - m increased in acute bacterial infections.
 - b. **eosinophils**
 - m 1-3% of total WBC's;
 - m kill parasites and help control **allergic reactions**;
 - m increased during parasitic infections:
 1. tapeworm
 2. hookworm.
 - m Release histamine during allergic reactions.
 - c. **basophils**
 - m <1% of total WBC's;
 - m release **heparin** which inhibits blood clotting;
 - m release **histamine**, a vasodilator helpful inflammatory responses.
 - d. **monocytes**
 - m 3-9% of total WBC's;
 - m **phagocytosis**;
 - m increased during typhoid fever, malaria, mononucleosis.
 - e. **lymphocytes**
 - m 25-33% of total WBC's;
 - m produce **antibodies** that act against specific foreign substances (immunity);
 - m increased during TB, whooping cough.

CHAPTER 14: CARDIOVASCULAR SYSTEM: BLOOD

III. Blood Cells (continued)

B. WBC's (continued)

3. Average WBC count (WCC) = **5-10000 wbc's / mm³ blood;**
 - a. Number of wbc's increases during infections;
 - m leukocytosis = WCC > 10000;
 - m leukopenia = WCC < 5000;
4. **Differential WCC** indicates % of each particular leukocyte;
5. **Diapedesis** = process by which leukocytes move through blood vessel walls to enter tissues;
See Fig 14.14, page 531.
6. **Leukemia** = abnormal (uncontrolled) production of specific types of immature leukocytes (see below).

C. Platelets = thrombocytes

1. Fragments of giant cells called megakaryocytes;
 2. Normal count = **130-360000 platelets/ mm³ blood;**
 3. Function = **blood clotting** (will be discussed in more detail later)
- * ALL BLOOD CELLS ARE FORMED FROM THE SAME LARGE PRIMITIVE CELL CALLED A **HEMOCYTOBLAST** (See Fig 14.3, page 523).
- * Summary of Formed Elements in Table 14.6, page 534.

CHAPTER 14: CARDIOVASCULAR SYSTEM: BLOOD

III. D. Major Blood Cell Summary Table (Keyed on page 292 of this outline)

Major Blood Cell Type			
Scientific Name			
Circulating Concentration/ mm ³ blood			
General Function			
Key Characteristic			

E. White Blood Cell Summary Table (Keyed on page 292 of this outline)

Specific WBC	Function/ Event of Increase?	Differential %	Typical Sketch

CHAPTER 14: CARDIOVASCULAR SYSTEM: BLOOD

IV. **BLOOD PLASMA** (See Fig 14.1 page 521, Fig 14.2 page 522, & Fig 14.16, pg 534).

Blood plasma is clear, yellow liquid, composed of proteins, nutrients, gases, electrolytes, and many more substances.

A. **WATER** (solvent, transport, temperature regulation);

B. **Plasma Proteins:** **See Table 14.7, page 535.**
(all produced in the liver)

1. **albumin;**
 - a. maintains osmotic pressure of cells (0.9%) and
 - b. transports fatty acids;
2. **globulins** α β γ
 - a. antibodies;
3. **fibrinogen;**
 - a. blood clotting.

C. **Plasma Nutrients:**

1. amino acids,
2. monosaccharides (i.e. glucose),
3. lipoproteins: See Table 14.8, page 536.

D. **Plasma Wastes:**

1. urea (amino acid metabolism),
2. uric acid (nucleotide metabolism),
3. creatinine (creatinine metabolism),
4. creatine (CP to recycle ADP to ATP in muscle & brain),
5. bilirubin.

E. **Plasma Gases:**

1. oxygen (needed for cellular respiration),
2. carbon dioxide (produced by cell respiration),
3. nitrogen (use unknown)

F. **Plasma Electrolytes:**

1. include sodium, potassium, calcium, magnesium, chloride, bicarbonate, phosphate, and sulphate;
2. Maintain osmotic pressure, Resting Membrane Potential, and pH.

G. **Regulatory Substances:**

1. enzymes,
2. hormones.

CHAPTER 14: CARDIOVASCULAR SYSTEM: BLOOD

V. **HEMOSTASIS** = stoppage of bleeding from a blood vessel.

A. 3 steps involved:

1. blood vessel spasm (vessel walls constrict);
2. platelet plug formation
 - a. See Fig 14.17, page 537.
 - b. platelets also release the hormone **serotonin** which causes further vasoconstriction of the vessel;
3. **blood coagulation** = formation of a blood clot;
 - a. complex cascade of events (positive feedback mechanism);
 - b. See Fig 14.19, page 540;
 - c. requires calcium ions;
 - d. Final step = fibrinogen -----> **fibrin**.

B. **Fibrinolytic System**

1. Fibrinolytic system provides checks and balances so that blood clotting does not go awry;
2. Fibrinolytic substances include:
 - a. tissue plasminogen activator (TPA):
 - m naturally produced
 - m injected quickly after MI to dissolve coronary thrombus(i).
 - b. Heparin is an anticoagulant:
 - m naturally produced by basophils and mast cells;
 - m pharmacologic agent extracted from lung tissues of animals;
 - m used during open heart surgery and hemodialysis.
 - c. Warfarin (Coumadin) another anticoagulant:
 - m given to patients prone to thrombosis;
 - m slower acting than heparin.

See CA 14.3 on page 543.

CHAPTER 14: CARDIOVASCULAR SYSTEM: BLOOD

VI. BLOOD GROUPS/TRANSFUSIONS

A. Significance

1. There are **antigens** present on the cell membrane surface of our red blood cells;
2. Our plasma contains substances called **antibodies**;
3. If the rbc antigen (donor) and plasma antibody (recipient) are the same, the serious condition of **hemolysis** (bursting) of rbc's will occur.

* In the laboratory, this situation can be simulated, however the result is termed **agglutination** = clumping of red blood cells.

B. Blood types: See Fig 14.21, page 545.

1. inherited trait;
2. determined by the antigens on a person's rbc's;
3. 4 types: A, B, AB, O
 - a. Type A blood = antigen A on rbc's;
 - b. Type B blood = antigen B on rbc's;
 - c. Type AB blood = both antigen A & B on rbc's;
 - d. Type O = neither A or B antigen on rbc's.

D. Antibodies in plasma: (See above figure)

1. Shortly after birth, we spontaneously develop antibodies against rbc antigens, that our not our own.
2. Antibodies formed include:
 - a. Persons with Type A blood, develop Anti-B antibodies;
 - b. Persons with Type B blood, develop Anti-A antibodies;
 - c. Persons with Type AB blood, do not develop either Anti-A or Anti-B antibodies;
 - d. Persons with Type O blood, develop both Anti-A and Anti-B antibodies.

CHAPTER 14: CARDIOVASCULAR SYSTEM: BLOOD

VI. BLOOD GROUPS/TRANSFUSIONS (continued):

E. Summary of ABO Interactions: (This Table is keyed on page 293 of this outline)

When considering blood transfusion reactions, the most important factor to consider is **the antibodies present in the recipient's plasma!**

BLOOD TYPE				
ANTIGEN ON RBC'S				
ANTIBODIES IN PLASMA				
COMPATIBLE DONORS				
INCOMPATIBLE DONORS				
GENOTYPE				
PHENOTYPE				

- * A person with **type O blood** is considered the **universal donor**.
- * A person with **type AB blood** is considered the **universal recipient**.

CHAPTER 14: CARDIOVASCULAR SYSTEM: BLOOD

VI. Blood Groups/Transfusions (continued)

F. Rh Factor:

1. inherited trait;
2. studied in rhesus monkeys (thus, Rh);
3. group of antigens present on rbc's = Rh positive; lack of antigens on rbc's = Rh negative;
4. Rh antibodies do not form spontaneously, but will form in Rh negative persons in response to stimulation:
 - a. Initial exposure (transfusion, etc.) does not produce harmful effects, however the Rh negative person has now been sensitized (i.e. they can produce anti-Rh antibodies);
 - b. Additional exposure (transfusion, etc.) causes serious hemolysis to occur.
5. **Erythroblastosis fetalis** =hemolytic disease of the newborn (HDN)
See Figure 14.23, page 547.
 - a. Scheme:
 - m Rh-negative mother becomes pregnant with Rh-positive baby;
 - m Pregnancy uneventful, but during birth, baby's blood enters the mother's circulation and causes her to produce anti-Rh antibodies;
 - m Mother conceives a second Rh-positive baby;
 - m Mother's anti-Rh antibodies can now pass through the placenta and enters baby's circulation;
 - m The baby's rbc's hemolyze resulting in this fatal condition.
 - b. Usually, no longer a problem because of the administration of a drug called **RhoGAM** which destroys the mother's anti-Rh antibodies.

CHAPTER 14: CARDIOVASCULAR SYSTEM: BLOOD

VII. Blood Disorders

- A. Sickle Cell Disease (page 522 & 524)
- B. Hemochromatosis (page 525)
- C. Pernicious Anemia (page 527)
- D. Anemias (Table 14.4, page 529)
- E. Chronic Granulomatous Disease (page 527)
- F. Porphyria (CA 14.1, page 539)
- G. Edema (page 535)
- H. Leukemia (CA 14.2, page 533)
- I. Thrombosis (page 539)
- J. Thrombocytopenia (page 542)
- K. Coagulation Disorders (CA 14.4, page 544)

VIII. Other Interesting Topics

- A. The Medicinal Leech (CA 14.3, page 543)
- B. Replacing Blood (CA 14.5, page 548)

CHAPTER 14: CARDIOVASCULAR SYSTEM: BLOOD

Major Blood Cell Summary Table (outline page 285)

Major Blood Cell Type	red blood cell	white blood cell	platelet
Scientific Name	erythrocyte	leukocyte	thrombocyte
Circulating Concentration/ mm ³ blood	4-6 million/ mm ³ blood	5-10,000/ mm ³ blood	130,000-360,000/ mm ³ blood
General Function	transportation of oxygen	fight infection	blood clotting
Key Characteristic	see page 38	see page 39-40	are fragments of giant megakaryocyte

White Blood Cell Summary Table (outline page 260)

Specific WBC	Function/ Event of Increase?	Differential %	Typical Sketch
neutrophil	general phagocytosis; acute bacterial infections	54%-62%	see page 538
eosinophil	kills parasites; helps control inflammation and allergic reactions	1%-3%	see page 540
basophil	releases heparin (natural anticoagulant) and histamine (inflammation)	less than 1%	see page 540
monocyte	phagocytosis of large particles; typhoid, malaria, mononucleosis	3%-9%	see page 540
lymphocyte	produce antibodies/immunity; TB, whooping cough	25%-33%	see page 540

CHAPTER 14: CARDIOVASCULAR SYSTEM: BLOOD

Summary of ABO Interactions (outline page 289)

BLOOD TYPE	A	B	AB	O
Antigen on rbc's	A	B	A and B	neither A or B
Antibodies in plasma	B	A	neither A or B	both A and B
Compatible donors	A, O	B, O	AB, A, B, O	O
Incompatible donors	B, AB	A, AB	NONE	A, B, AB
Genotype	$I^A I^A$ OR $I^A i$	$I^B I^B$, $I^B i$	$I^A I^B$	ii
Phenotype	type A	type B	type AB	type O