Chapter 6
Cardiovascular System: Blood

What are the functions of blood?
• Transportation: oxygen, nutrients, wastes, carbon dioxide and hormones
• Defense: against invasion by pathogens
• Regulatory functions: body temperature, water-salt balance and body pH

6.1 Blood: An overview

What is the composition of blood?
• Remember: blood is a fluid connective tissue
• Formed elements: produced in red bone marrow
  – Red blood cells/erythrocytes (RBC)
  – White blood cells/leukocytes (WBC)
  – Platelets
• Plasma:
  – 92% water and 8% salts and organic molecules
  – Plasma proteins are the most abundant molecules
3 major types of plasma proteins

- Albumins – most abundant and important for plasma’s osmotic pressure as well as transportation
- Globulins – also important in transportation
- Fibrinogen – important for the formation of blood clots

The structure of red blood cells is important to their function

- Lack a nucleus and few organelles
- Biconcave shape increases surface area
- Contain about 280 million hemoglobin molecules that bind 4 molecules of \( O_2 \) each
How is carbon dioxide transported?

- 68% as a bicarbonate ion in the plasma
- 25% in red blood cells
- 7% as carbon dioxide in the plasma

Production of red blood cells

- Produced in the red bone marrow
- Lifespan of about 120 days
- Erythropoietin (EPO) is excreted by kidney cells and moves to red marrow when oxygen levels are low
- Old cells are destroyed by the liver and spleen

What is blood doping?

- Any method of increasing the number of RBC's to increase athletic performance
- It allows more efficient delivery of oxygen and reducing fatigue
- EPO is injected into a person months prior to an athletic event
- Potential to result in death due to thickening of blood that leads to a heart attack

What disorders involve RBC's?

- Anemia – a condition resulting from too few RBC's or hemoglobin that causes a run-down feeling
- Sickle-cell anemia – genetic disease that causes RBC's to be sickle shaped that tend to rupture
- Hemolytic disease of the newborn – a condition with incompatible blood types that leads to rupturing of blood cells in a baby before and continuing after birth
White blood cells

- Derived from red bone marrow
- Large blood cells that have a nucleus
- Production is regulated by colony-stimulating factor (CSF)
- Can be found in the blood as well as in tissues
- Fight infection and an important part of the immune system
- Some live days and others live months or years

How are white blood cells categorized?

- Granular – contain noticeable granules, lobed nuclei
  - Eosinophil
  - Basophil
  - Neutrophil

- Agranular – no granules, nonlobed nuclei
  - Lymphocyte
  - Monocyte

Neutrophils

- About 50-70% of all WBC's
- Contain a multi-lobed nucleus
- Upon infection they move out of circulation into tissues to use phagocytosis to engulf pathogens
Eosinophils
- Small percentage of WBC’s
- Contain a bilobed nucleus
- Many large granules function in parasitic infections and play a role in allergies

Basophil
- Small percentage of WBC’s
- Contain a U-shaped or lobed nucleus
- Release histamine related to allergic reactions

Lymphocyte
- About 25-35% of all WBC’s
- Large nucleus that takes up most of the cytoplasm
- Develop into B and T cells that are important in the immune system

Monocyte
- Relatively uncommon WBC’s
- Largest WBC with horseshoe-shaped nucleus
- Take residence in tissues and develop into macrophages
- Macrophages use phagocytosis to engulf pathogens
**How do blood cells leave circulation?**

**What disorders involve WBC’s?**

- Severe combined immunodeficiency disease (SCID) — an inherited disease in which stem cells of WBC’s lack an enzyme that allows them to fight any infection
- Leukemia — a group of cancers that affect white blood cells in which cells proliferate without control
- Infectious mononucleosis — also known as the “kissing disease” occurs when the Epstein-Barr virus (EBV) infects lymphocytes resulting in fatigue, sore throat and swollen lymph nodes

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**Fig. 6.7 Platelets and blood clotting**

**Platelets**

- Made of fragments of large cells called megakaryocytes made in the red bone marrow
- About 200 billion are made per day
- Function in blood clotting
- Blood proteins named thrombin and fibrinogen are important for blood clotting by leading to fibrin threads that catch RBC’s
6.4 Platelets and blood clotting

How do platelets clot blood?

- Thromboembolism – when a clot forms and breaks off from its site of origin and plugs another vessel
- Hemophilia – a genetic disorder that results in a deficiency of a clotting factor so that when a person damages a blood vessel they are unable to properly clot their blood both internally and externally

6.5 Blood typing and transfusions

Terminology to help understand ABO blood typing

- Antigen - a foreign substance, often a polysaccharide or a protein, that stimulates an immune response
- Antibody – proteins made in response to an antigen in the body and bind to that antigen

Fig. 6.8b

What disorders involve platelets?

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What determines the A, B, AB or O blood type?
• Presence and/or absence of 2 blood antigens, A and B
• Type of antibodies present
• Antibodies are only present for those antigen lacking on the cells because these proteins recognize and bind the protein they are named after

How can you remember what each blood type means?
• Blood types are named after the protein antigens that are present on the surface of their cell, except type O that entirely lacks A and B proteins
• Blood types only have antibodies to antigens they do not have on the surface of their cells
• For example: Type A blood
  – Have A proteins on its surface
  – Has B antibodies
• What can you say about someone with type AB blood?

Looking at each blood type in the ABO blood system

How can you determine if blood types are compatible for a blood transfusion?
• First, consider the antigens found on the blood transfusion recipient
• Second, consider the antibodies found in the donor blood
• If the antibodies in the donor blood can recognize the antigen on the recipient’s blood then the blood will agglutinate (clump) and cause rejection
Testing your understanding

- Can a person with blood type O accept blood type A without agglutination occurring? Why or why not?
- Why can people with AB blood type accept more blood types than people with type O, A or B?
- Which blood type is able to be used most often as a donor blood type? Why?

What about Rh blood groups?

- The Rh factor is often included when expressing a blood type by naming it positive or negative.
- People with the Rh factor are positive and those without it are negative.
- Rh antibodies only develop in a person when they are exposed to the Rh factor from another's blood (usually a fetus).

When is the Rh factor important?

- During pregnancy under these conditions:
  - Mom: Rh-
  - Dad: Rh+
  - Fetus: Rh+ (possible with the parents above)
- In this case above some Rh+ blood can leak from the fetus to the mother during birth causing the mother to make Rh antibodies.
- This can be a problem if the mother has a second fetus that is Rh+ because she now has antibodies that can leak across the placenta and attack the fetus.
- This condition is known as hemolytic disease of the newborn that can lead to retardation and even death.

Visualizing how hemolytic disease of the newborn happens
How can hemolytic disease of the newborn be prevented?

- Rh- women are given an injection of anti-Rh antibodies no later than 72 hours after birth to an Rh+ baby.
- These antibodies attack fetal red blood cells in the mother before the mother’s immune system can make antibodies.
- This will have to be repeated if an Rh- mother has another Rh+ baby in case she has later pregnancies.

6.5 Blood typing and transfusions

6.6 Homeostasis