9. Blood is connective tissue with cells suspended in plasma
10. Cardiovascular diseases are the leading cause of death in the United States and most other developed nations
9. Blood is a connective tissue with cells suspended in plasma

- In invertebrates with open circulation, blood (hemolymph) is not different from interstitial fluid.

- However, blood in the closed circulatory systems of vertebrates is a specialized connective tissue consisting of several kinds of cells suspended in a liquid matrix called **plasma**.

- The plasma includes the cellular elements (cells and cell fragments), which occupy about 45% of the blood volume, and the transparent, straw-colored plasma.
The plasma, about 55% of the blood volume, consists of water, ions, various plasma proteins, nutrients, waste products, respiratory gases, and hormones, while the cellular elements include red and white blood cells and platelets.
**Plasma 55%**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Major functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>Solvent for carrying other substances</td>
</tr>
<tr>
<td>Ions</td>
<td></td>
</tr>
<tr>
<td>Sodium</td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td></td>
</tr>
<tr>
<td>Chloride</td>
<td></td>
</tr>
<tr>
<td>Bicarbonate</td>
<td></td>
</tr>
<tr>
<td>Plasm proteins</td>
<td></td>
</tr>
<tr>
<td>Albumin</td>
<td></td>
</tr>
<tr>
<td>Fibrinogen</td>
<td></td>
</tr>
<tr>
<td>Immunoglobulins (antibodies)</td>
<td></td>
</tr>
<tr>
<td>Substances transported by blood</td>
<td></td>
</tr>
<tr>
<td>Nutrients (e.g., glucose, fatty acids, vitamins)</td>
<td></td>
</tr>
<tr>
<td>Waste products of metabolism</td>
<td></td>
</tr>
<tr>
<td>Respiratory gases (O₂ and CO₂)</td>
<td></td>
</tr>
<tr>
<td>Hormones</td>
<td></td>
</tr>
</tbody>
</table>

**Cellular elements 45%**

<table>
<thead>
<tr>
<th>Cell type</th>
<th>Number (per mm³ of blood)</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erythrocytes (red blood cells)</td>
<td>5–6 million</td>
<td>Transport oxygen and help transport carbon dioxide</td>
</tr>
<tr>
<td>Leukocytes (white blood cells)</td>
<td>5000–10,000</td>
<td>Defense and immunity</td>
</tr>
<tr>
<td>Basophil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eosinophil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutrophil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lymphocyte</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monocyte</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platelets</td>
<td>250,000–400,000</td>
<td>Blood clotting</td>
</tr>
</tbody>
</table>

Fig. 42.14
• Blood plasma is about 90% water.

• Dissolved in the plasma are a variety of ions, sometimes referred to as blood electrolytes,
  • These are important in maintaining osmotic balance of the blood and help buffer the blood.
  • Also, proper functioning of muscles and nerves depends on the concentrations of key ions in the interstitial fluid, which reflects concentrations in the plasma.

• Plasma carries a wide variety of substances in transit from one part of the body to another, including nutrients, metabolic wastes, respiratory gases, and hormones.
• The plasma proteins have many functions.
  • Collectively, they act as buffers against pH changes, help maintain osmotic balance, and contribute to the blood’s viscosity.
  • Some specific proteins transport otherwise-insoluble lipids in the blood.
  • Other proteins, the immunoglobulins or antibodies, help combat viruses and other foreign agents that invade the body.
  • Fibrinogen proteins help plug leaks when blood vessels are injured.
    • Blood plasma with clotting factors removed is called serum.

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• Suspended in blood plasma are two classes of cells: **red blood cells** which transport oxygen, and **white blood cells**, which function in defense.

• A third cellular element, **platelets**, are pieces of cells that are involved in clotting.

• Red blood cells, or **erythrocytes**, are by far the most numerous blood cells.
  • Each cubic millimeter of blood contains 5 to 6 million red cells, 5,000 to 10,000 white blood cells, and 250,000 to 400,000 platelets.
  • There are about 25 trillion red cells in the body’s 5 L of blood.
• The main function of red blood cells, oxygen transport, depends on rapid diffusion of oxygen across the red cell’s plasma membranes.

• Human erythrocytes are small biconcave disks, presenting a great surface area.

• Mammalian erythrocytes lack nuclei, an unusual characteristic that leaves more space in the tiny cells for hemoglobin, the iron-containing protein that transports oxygen.

• Red blood cells also lack mitochondria and generate their ATP exclusively by anaerobic metabolism.
• An erythrocyte contains about 250 million molecules of **hemoglobin**.
  
  • Each hemoglobin molecule binds up to four molecules of $O_2$.
  
  • Recent research has also found that hemoglobin also binds the gaseous molecule nitric oxide (NO).
  
  • As red blood cells pass through the capillary beds of lungs, gills, or other respiratory organs, oxygen diffuses into the erythrocytes and hemoglobin binds $O_2$ and NO.
  
  • In the systemic capillaries, hemoglobin unloads oxygen and it then diffuses into body cells.
  
  • The NO relaxes the capillary walls, allowing them to expand, helping delivery of $O_2$ to the cells.
• There are five major types of white blood cells, or **leukocytes**: monocytes, neutrophils, basophils, eosinophils, and lymphocytes.

• Their collective function is to fight infection.
  
  • For example, monocytes and neutrophils are phagocytes, which engulf and digest bacteria and debris from our own cells.
  
  • Lymphocytes develop into specialized B cells and T cells, which produce the immune response against foreign substances.
  
  • White blood cells spend most of their time outside the circulatory system, patrolling through interstitial fluid and the lymphatic system, fighting pathogens.
• The third cellular element of blood, platelets, are fragments of cells about 2 to 3 microns in diameter.

• They have no nuclei and originate as pinched-off cytoplasmic fragments of large cells in the bone marrow.

• Platelets function in blood clotting.
• The cellular elements of blood wear out and are replaced constantly throughout a person’s life.
  
  • For example, erythrocytes usually circulate for only about 3 to 4 months and are then destroyed by phagocytic cells in the liver and spleen.
  
  • Enzymes digest the old cell’s macromolecules, and the monomers are recycled.
  
  • Many of the iron atoms derived from hemoglobin in old red blood cells are built into new hemoglobin molecules.
• Erythrocytes, leukocytes, and platelets all develop from a single population of cells, **pluripotent stem cells**, in the red marrow of bones, particularly the ribs, vertebrae, breastbone, and pelvis.

• “Pluripotent” means that these cells have the potential to differentiate into any type of blood cells or cells that produce platelets.

• This population renews itself while replenishing the blood with cellular elements.
Lymphoid stem cells

Pluripotent stem cells (in bone marrow)

Myeloid stem cells

Erythrocytes

Platelets

B cells  T cells

Lymphocytes

Monocytes

Neutrophils

Basophils

Eosinophils

Fig. 42.13
• A negative-feedback mechanism, sensitive to the amount of oxygen reaching the tissues via the blood, controls erythrocyte production.
  
  • If the tissues do not produce enough oxygen, the kidney converts a plasma protein to a hormone called **erythropoietin**, which stimulates production of erythrocytes.
  
  • If blood is delivering more oxygen than the tissues can use, the level of erythropoietin is reduced, and erythrocyte production slows.
Through a recent breakthrough in isolating and culturing pluripotent stem cells, researchers may soon have effective treatments for a number of human diseases, such as leukemia.

- Individuals with leukemia have a cancerous line of stem cells that produce leukocytes.

- These cancerous cells crowd out cells that make red blood cells and produce an unusually high number of leukocytes, many of which are abnormal.

- One strategy now being used experimentally for treating leukemia is to remove pluripotent stem cells from a patient, destroy the bone marrow, and restock it with noncancerous pluripotent cells.
• Blood contains a self-sealing material that plugs leaks from cuts and scrapes.

• A clot forms when the inactive form of the plasma protein **fibrinogen** is converted to **fibrin**, which aggregates into threads that form the framework of the clot.

• The clotting mechanism begins with the release of clotting factors from platelets.

• An inherited defect in any step of the clotting process causes **hemophilia**, a disease characterized by excessive bleeding from even minor cuts and bruises.
(1) The clotting process begins when the endothelium of a vessel is damaged and connective tissue in the wall is exposed to blood.

- Platelets adhere to collagen fibers and release a substance that makes nearby platelets sticky.

(2) The platelets form a plug.

(3) The seal is reinforced by a clot of fibrin when vessel damage is severe.
Fig. 42.16

1. Injury to lining of blood vessel exposes connective tissue; platelets adhere
2. Platelet plug forms
3. Fibrin clot with trapped cells

- Collagen fibers
- Platelet releases chemicals that make nearby platelets sticky
- Platelet plug
- Fibrin

Clotting factors from:
- Platelets
- Damaged cells
- Plasma (factors include calcium, vitamin K)

Prothrombin → Thrombin

Fibrinogen → Fibrin
• Anticlotting factors in the blood normally prevent spontaneous clotting in the absence of injury.

• Sometimes, however, platelets clump and fibrin coagulates within a blood vessel, forming a clot called a thrombus, and blocking the flow of blood.

• These potentially dangerous clots are more likely to form in individuals with cardiovascular disease, diseases of the heart and blood vessels.
10. Cardiovascular diseases are the leading cause of death in the United States and most other developed nations

- More than half the deaths in the United States are caused by cardiovascular diseases, diseases of the heart and blood vessels.

- The final blow is usually a heart attack or stroke.
  - A heart attack is the death of cardiac muscle tissue resulting from prolonged blockage of one or more coronary arteries, the vessels that supply oxygen-rich blood to the heart.

  - A stroke is the death of nervous tissue in the brain.
• Heart attacks and strokes frequently result from a thrombus that clogs a coronary artery or an artery in the brain.

• The thrombus may originate at the site of blockage or it may develop elsewhere and be transported (now called an embolus) until it becomes lodged in an artery too narrow for it to pass.

• Cardiac or brain tissue downstream of the blockage may die from oxygen deprivation.

• The effects of a stroke and the individual’s chance of survival depend on the extent and location of the damaged brain tissue.
• If damage in the heart interrupts the conduction of electrical impulses through cardiac muscle, heart rate may change drastically or the heart may stop beating altogether.

• Still, the victim may survive if heartbeat is restored by cardiopulmonary resuscitation (CPR) or some other emergency procedure within a few minutes of the attack.
• The suddenness of a heart attack or stroke belies the fact that the arteries of most victims had become gradually impaired by a chronic cardiovascular disease known as **atherosclerosis**.

• Growths called plaques develop in the inner wall of the arteries, narrowing their bore.

![Fig. 42.17](image-url)
• At plaque sites, the smooth muscle layer of an artery thickens abnormally and becomes infiltrated with fibrous connective tissue and lipids such as cholesterol.

• In some cases, plaques also become hardened by calcium deposits, leading to **arteriosclerosis**, commonly known as hardening of the arteries.

• Vessels that have been narrowed are more likely to trap an embolus and are common sites for thrombus formation.
• As atherosclerosis progresses, arteries become more and more clogged and the threat of heart attack or stroke becomes much greater, but there may be warnings of this impending threat.

• For example, if a coronary artery is partially blocked, a person may feel occasional chest pains, a condition known as angina pectoris.

• This is a signal that part of the heart is not receiving enough blood, especially when the heart is laboring because of physical or emotional stress.

• However, many people with atherosclerosis experience no warning signs and are unaware of their disease until catastrophe strikes.
• **Hypertension** (high blood pressure) promotes atherosclerosis and increases the risk of heart disease and stroke.

  • According to one hypothesis, high blood pressure causes chronic damage to the endothelium that lines arteries, promoting plaque formation.

  • Hypertension is simple to diagnose and can usually be controlled by diet, exercise, medication, or a combination of these.
• To some extent, the tendency to develop hypertension and atherosclerosis is inherited.

• Nongenetic factors include smoking, lack of exercise, a diet rich in animal fat, and abnormally high levels of cholesterol in the blood.

• One measure of an individual’s cardiovascular health or risk of arterial plaques can be gauged by the ratio of **low-density lipoproteins** (LDLs) to **high-density lipoproteins** (HDLs) in the blood.
  
  • LDL is associated with depositing of cholesterol in arterial plaques.
  
  • HDL may reduce cholesterol deposition.