Blood is a liquid connective tissue consisting of cells surrounded by a liquid matrix (plasma).

- The cellular components (formed elements) of blood include red blood cells, white blood cells and platelets.
- The plasma portion of blood consists of water, proteins and other solutes.
Functions and Properties of Blood

Blood transports oxygen, carbon dioxide, nutrients, hormones, heat and waste products.

Blood regulates homeostasis of all body fluids, pH, body temperature and water content of cells.

Blood protects against excessive loss by clotting and against infections through the use of white blood cells.
Lymphocytes are able to live for years while most other blood cells live for hours, days, or weeks.

The number of red blood cells and platelets remains rather steady while that of white blood cells varies depending on invading pathogens and other foreign antigens.

The process of producing blood cells is hemopoiesis (hematopoiesis). Pluripotent stem cells differentiate into each of the different types of blood cells.
Red blood cells (erythrocytes) contain the protein hemoglobin that is used to carry oxygen to all cells and to carry 23% of total carbon dioxide to the lungs.

- Each hemoglobin molecule contains an iron ion which allows each molecule to bind four oxygen molecules.
- Red blood cells have no nucleus or other organelles and are biconcave discs. The lack of a nucleus and the shape allow the cells to efficiently carry oxygen.

Hemoglobin is also involved in regulating blood flow and blood pressure via the release of nitric oxide which causes vasodilation that improves blood flow and enhances oxygen delivery.

- Red blood cells also contain carbonic anhydrase which catalyzes the conversion of carbon dioxide and water to carbonic acid. This compound transports about 70% of carbon dioxide in the plasma. It is also a buffer.
Red Blood Cells

- Red blood cells live for only about 120 days. Dead cells are removed from the circulation by the spleen and liver.
- Breakdown products from the cells are recycled and reused.

Erythropoiesis (production of red blood cells) begins in the red bone marrow. Reticulocytes (immature red blood cells) enter the circulation and mature in 1 to 2 days.

Erythropoietin, a hormone released by the kidneys in response to hypoxia (lowered oxygen concentration) stimulates differentiation of hematopoietic stem cells into erythrocytes.
White Blood Cells

- **White blood cells (leukocytes)** contain a nucleus and organelles, but no hemoglobin.
- Leukocytes are classified as either **granular** (containing vesicles that appear when the cells are stained) or **agranular** (containing no granules).
- Granular leukocytes: **neutrophils, eosinophils, basophils**
- Agranular leukocytes: **lymphocytes, monocytes**
White Blood Cells may live for several months or years. Their main function is to combat invading microbes.

During an invasion, many white blood cells are able to leave the bloodstream and collect at sites of invasion. The process is called emigration (diapedesis).
In general, an **elevation in the white blood count** usually indicates an **infection** or **inflammation**.

- A **low white blood cell count** may develop due to several causes.
- A **differential white blood cell count** will help to determine if a problem exists.

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**Platelets**

- **Platelets** are used to **clot the blood**.
- Under the influence of the hormone **thrombopoietin**, hemopoietic stem cells differentiate into **platelets**.
- **Megakaryocytes** in red bone marrow splinter into 2000–3000 fragments to create the platelets that contain many vesicles but no nucleus.
- Platelets survive for only 5 to 9 days.
Bone marrow transplants are performed to replace cancerous red bone marrow with normal red bone marrow. The donor’s marrow is usually collected from the iliac crest of the hip bone.

Stem cells collected from an umbilical cord after birth are frozen and may also be used and have advantages over bone marrow transplants.
Hemostasis

Hemostasis means to stop bleeding. The process involves:

- Vascular spasm
- Platelet plug formation
- Blood clotting (coagulation)
Blood clotting involves several **clotting (coagulation) factors** identified by Roman numerals and divided into three stages.

The three stages are the **extrinsic pathway, intrinsic pathway** and **common pathway**.
Once the clot forms, it **consolidates** (tightens) to pull the edges of the damaged vessel together.

- **Vitamin K** is needed for normal clot formation although it is not directly involved. It is used in the synthesis of 4 clotting factors.
- Small, unwanted clots are usually dissolved by **plasmin (fibrinolysin)**.

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**Blood Groups and Blood Types**

- Blood is characterized into different **blood groups** based on the presence or absence of **glycoprotein and glycolipid antigens** (agglutinogens) on the surface of red blood cells.
- There are 24 blood groups and more than 100 antigens.
- Because these antigens are genetically controlled, blood types vary among different populations.
- Classification is based on antigens labeled A, B or AB with O being the absence of the antigens.
- An additional antigen, Rh, is present in 85% of humans.

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**TABLE 19.5**

<table>
<thead>
<tr>
<th>Blood Types in the United States</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>POPULATION GROUP</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>European-American</td>
</tr>
<tr>
<td>African-American</td>
</tr>
<tr>
<td>Korean-American</td>
</tr>
<tr>
<td>Japanese-American</td>
</tr>
<tr>
<td>Chinese-American</td>
</tr>
<tr>
<td>Native American</td>
</tr>
</tbody>
</table>

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Blood plasma usually contains **antibodies (agglutinins)** that react with A or B antigens. An individual will not have agglutinins against his or her own blood type.
In order to determine a person’s blood type, typing and cross-matching are performed.

A drop of blood is mixed with an antiserum that will agglutinate blood cells that possess agglutinogens that react with it.

At birth, small amounts of fetal blood leak into the maternal circulation. If the baby is Rh\(^+\) and the mother is Rh\(^-\), she will develop antibodies to the Rh factor.

During her next pregnancy with an Rh\(^+\) baby, when she transfers antibodies to the fetus (a normal occurrence), transferred anti Rh antibodies will attack some of the fetus’ red blood cells causing agglutination and hemolysis.
Sickle cell disease is a genetic anemia (oxygen-carrying capacity of the blood is reduced).

The red blood cells of individuals with this disease contain hemoglobin-S (Hb-S) that causes red blood cells to bend into a sickle shape when it gives up oxygen to the interstitial fluid.