Blood consists of a complex liquid **plasma** in which the cellular elements *erythrocytes, leukocytes,* and *platelets* are suspended.
Erythrocytes (**red blood cells**, or **RBCs**) are essentially plasma membrane enclosed bags of hemoglobin that transport O2 in the blood.
Leukocytes (**white blood cells**, or **WBCs**), the immune system's mobile defense units, are transported in the blood to sites of injury or of invasion by disease-causing microorganisms.
Platelets (thrombocytes) are important in hemostasis, the stopping of bleeding from an injured vessel.
Blood represents about 8% of total body weight and has an average volume of 5 liters in women and 5.5 liters in men. If you put a sample of whole blood in a test tube and treat it to prevent clotting, the heavier cells slowly settle to the bottom and the lighter plasma rises to the top. This process can be hastened by centrifuging, which quickly packs the cells in the bottom of the tube.
Because more than 99% of the cells are erythrocytes, the **hematocrit**, or **packed cell volume**, essentially represents the percentage of erythrocytes in the total blood volume.
The hematocrit averages about 42% for women and slightly higher, 45%, for men. Plasma accounts for the remaining volume.
Accordingly, the average volume of plasma in the blood is about 58% for women and 55% for men.
White blood cells and platelets, which are colorless and less dense than red cells, are packed in a thin, cream-colored layer, the *buffy coat,* on top of the packed red cell column. They are less than 1% of the total blood volume.

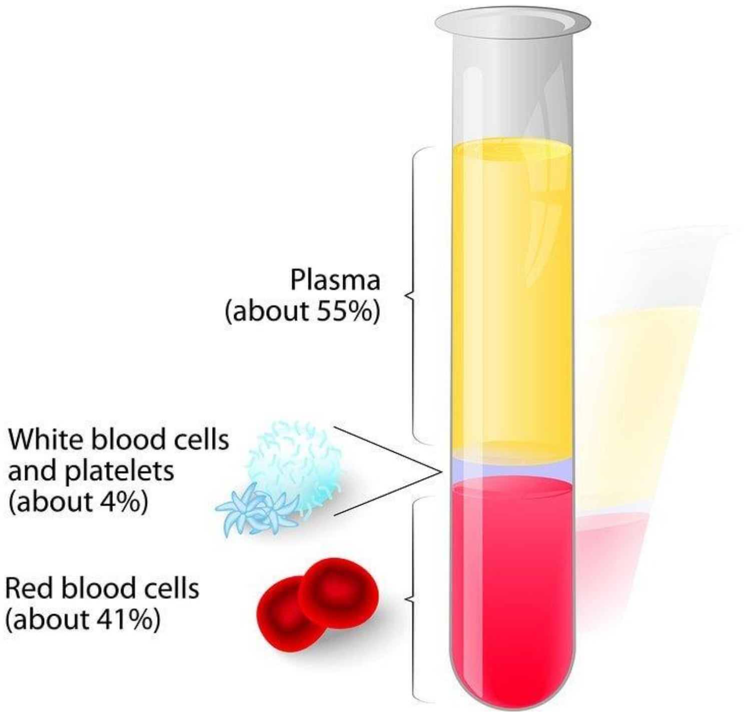


Figure : Blood contents

Plasma

Plasma, being a liquid, consists of 90% water. Plasma water is a medium for materials being carried in the blood. Also, plasma absorbs and distributes much of the heat generated metabolically within tissues, with only minimal changes in the temperature of the blood itself. As blood travels close to the surface of the skin, heat energy not needed to maintain body temperature is eliminated to the environment.

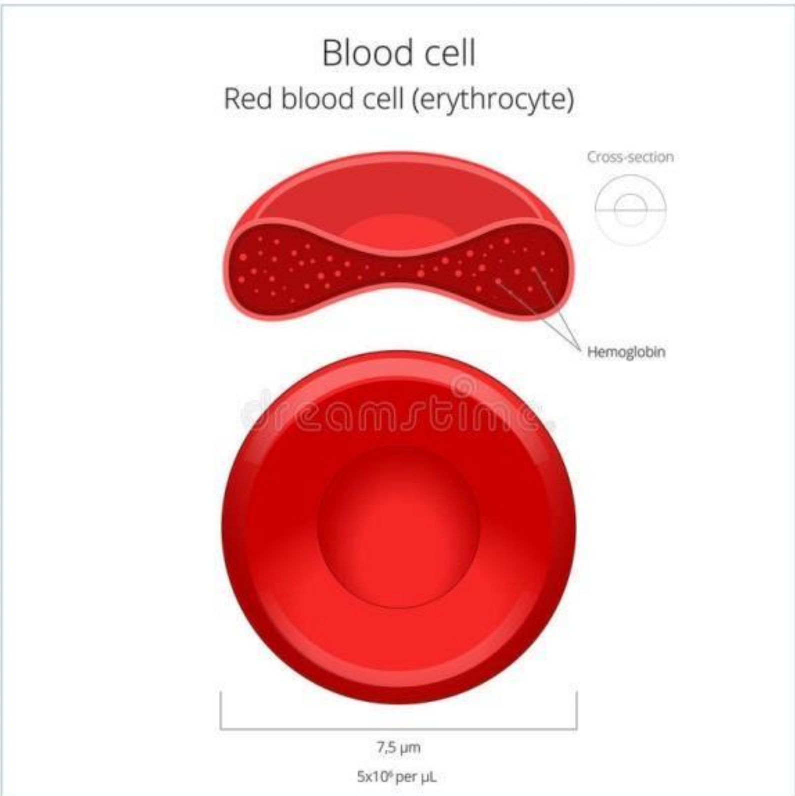
A large number of inorganic and organic substances are dissolved in the plasma. Inorganic constituents account for about 1% of plasma weight. The most abundant electrolytes (ions) in the plasma are Na1 and Cl2, the components of common salt. Smaller amounts of HCO3 2, K1, Ca21, and other ions are present.

The most plentiful organic constituents by weight are the plasma proteins, which make up 6% to 8% of plasma weight.

The remaining small percentage of plasma consists of other organic substances, including nutrients (such as glucose, amino acids, lipids, and vitamins), waste products (creatinine, bilirubin, and nitrogenous substances such as urea), dissolved gases (O2 and CO2), and hormones. Most of these substances are merely being transported in the plasma. Three groups of plasma proteins : *albumins, globulins,* and *fibrinogen*

Erythrocytes

Each milliliter of blood on average contains about 5 billion **erythrocytes (red blood cells,** or **RBCs)**, commonly reported clinically in a **red blood cell count** as 5 million cells per cubic millimeter (mm3). The shape and content of erythrocytes are ideally suited to carry out their primary function, transporting O2 in the blood.



Erythrocyte Structure

Three anatomic features of erythrocytes contribute to the efficiency with which they transport O2:

First, erythrocytes are flat, disc-shaped cells indented in the middle on both sides, like a doughnut with a flattened center instead of a hole (that is, they are biconcave discs 8 mm in diameter, 2 mm thick at the outer edges, and 1 mm thick in the center).

The biconcave shape provides a larger surface area for diffusion of O2 from the plasma across the membrane into the erythrocyte than a spherical cell of the same volume would.

A **second** structural feature that facilitates RBCs' transport function is their flexible membrane. Red blood cells, whose diameter is normally 8 mm, can deform amazingly as they squeeze single file through capillaries as narrow as 3 mm in diameter. Because they are extremely pliant, RBCs can travel through the narrow, tortuous capillaries to deliver their O2 cargo at the tissue level without rupturing in the process.

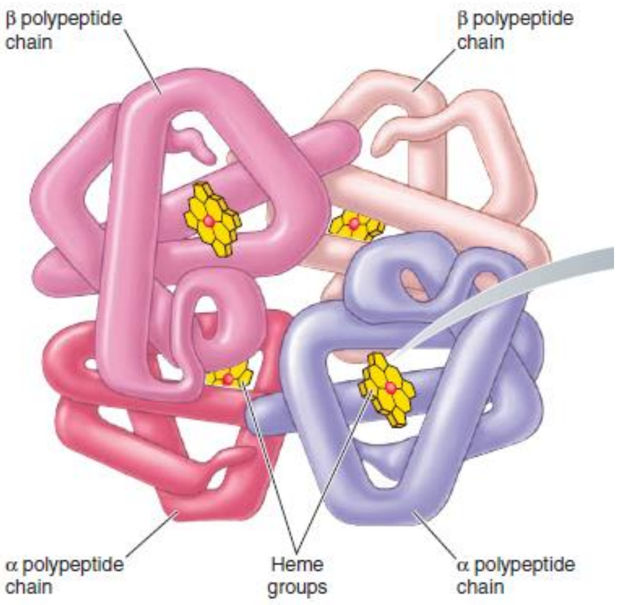
The **third** and most important anatomic feature that enables RBCs to transport O2 is the hemoglobin they contain.

Role of Hemoglobin

Hemoglobin is found only in red blood cells. A **hemoglobin** molecule has two parts:
(1) the **globin** portion, a protein made up of four highly folded polypeptide
chains (two a subunits and two b subunits)
(2) four iron groups known as **heme groups**, each of which is bound to one of the polypeptides.

Each of the four iron atoms can combine reversibly with one molecule of O2; thus, each hemoglobin molecule can pick up four O2 passengers in the lungs. Because O2 is poorly soluble in the plasma, 98.5% of the O2 carried in the blood is bound to hemoglobin

Hemoglobin is a pigment (that is, it is naturally colored). Because of its iron content, it appears reddish when combined with O2 and bluish when deoxygenated.



(a) Hemoglobin molecule

Lack of Nucleus and Organelles

To maximize its hemoglobin content, a single erythrocyte is stuffed with more than 250 million hemoglobin molecules, excluding almost everything else. (That means each RBC can carry more than 1 billion O2 molecules.) Red blood cells contain no nucleus or organelles.

During the cell's development, these structures are extruded to make room for more hemoglobin. Thus, an RBC is mainly a plasma membrane–enclosed sac full of hemoglobin.

The bone marrow continuously replaces worn-out erythrocytes.

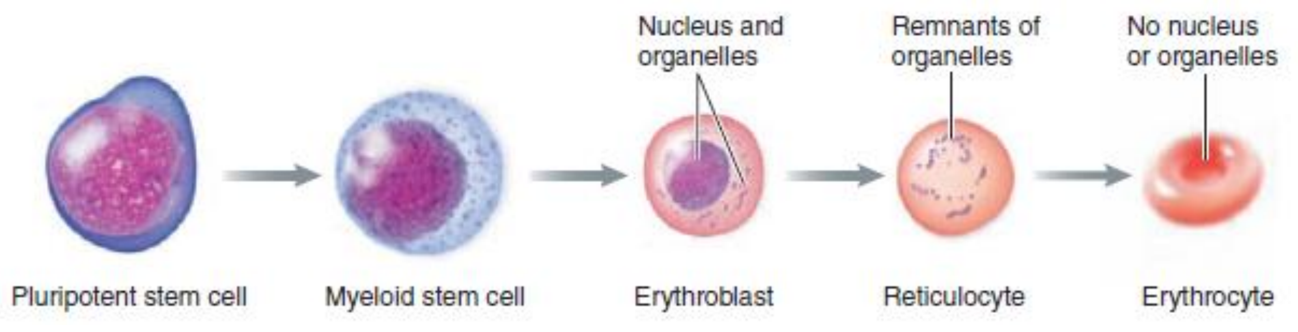
Each of us has a total of 25 trillion to 30 trillion RBCs streaming through our blood vessels at any given time . Yet these vital gas-transport vehicles are short-lived and must be replaced at the average rate of 2 million to 3 million cells per second.

Erythrocytes' Short Life Span

Without DNA, RNA, and ribosomes, red blood cells cannot synthesize proteins for cell repair, growth, and division or for renewing enzyme supplies. RBCs survive an average of only 120 days . During its short life span of 4 months, each erythrocyte travels about 700 miles as it circulates through the vasculature. As a red blood cell ages, its plasma membrane, which cannot be repaired, becomes fragile and prone to rupture as the cell squeezes through tight spots in the vascular system. Most old RBCs meet their final demise in the **spleen** because this organ's narrow, winding capillary network is a tight fit for these fragile cells.

Erythropoiesis

The bone marrow normally generates new red blood cells, a process known as **erythropoiesis**, at a rate to keep pace with the demolition of old cells.



Blood types depend on surface antigens on erythrocytes.

An **antigen** is a large, complex molecule that triggers a specific immune response against itself when it gains entry to the body. For example, antigens are found on the surface of foreign cells such as bacterial invaders. Certain types of white blood cells recognize antigens and produce specific antibodies against them. An **antibody** binds with the specific antigen against which it is produced and leads to the antigen's destruction by various means. Thus, the body rejects cells bearing antigens that do not match its own.

ABO Blood Types

The surface membranes of human erythrocytes contain inherited antigens that vary depending on blood type. Within the major blood group system, the **ABO system**, the erythrocytes of people with type A blood contain A antigens, those with type B blood contain B antigens, those with type AB blood have both A and B antigens, and those with type O blood do not have any A or B red blood cell surface antigens.

Accordingly, the plasma of type

A blood contains anti-B antibodies, type B blood contains anti- A antibodies, no antibodies related to the ABO system are present in type AB blood, and both anti-A and anti-B antibodies are present in type O blood.

ITABLE 11-2 ABO Blood Types

Blood Type	Antigens on Erythrocytes	Antibodies in Plasma
A	A	Anti-B
B	B	Anti-A
AB	A and B	No antibodies
O	No antigens	Both anti-A and anti-B

Transfusion Reaction

If a person is given blood of an incompatible type, two antigen–antibody interactions take place. By far, the more serious consequences arise from the effect of the antibodies in the recipient's plasma on the incoming donor erythrocytes.

The effect of the donor's

antibodies on the recipient's erythrocyte-bound antigens is less important unless a large amount of blood is transfused, because the donor's antibodies are so diluted by the recipient's plasma that little RBC damage takes place in the recipient.

Antibody interaction with an erythrocyte-bound antigen may result in agglutination (clumping) or hemolysis (rupture) of the attacked RBCs.

Rh Blood-Group System

People who have the **Rh factor** (an erythrocyte antigen first observed in rhesus monkeys, hence the designation Rh) are said to have *Rh-positive* blood, whereas those lacking the Rh factor are considered *Rh-negative.*

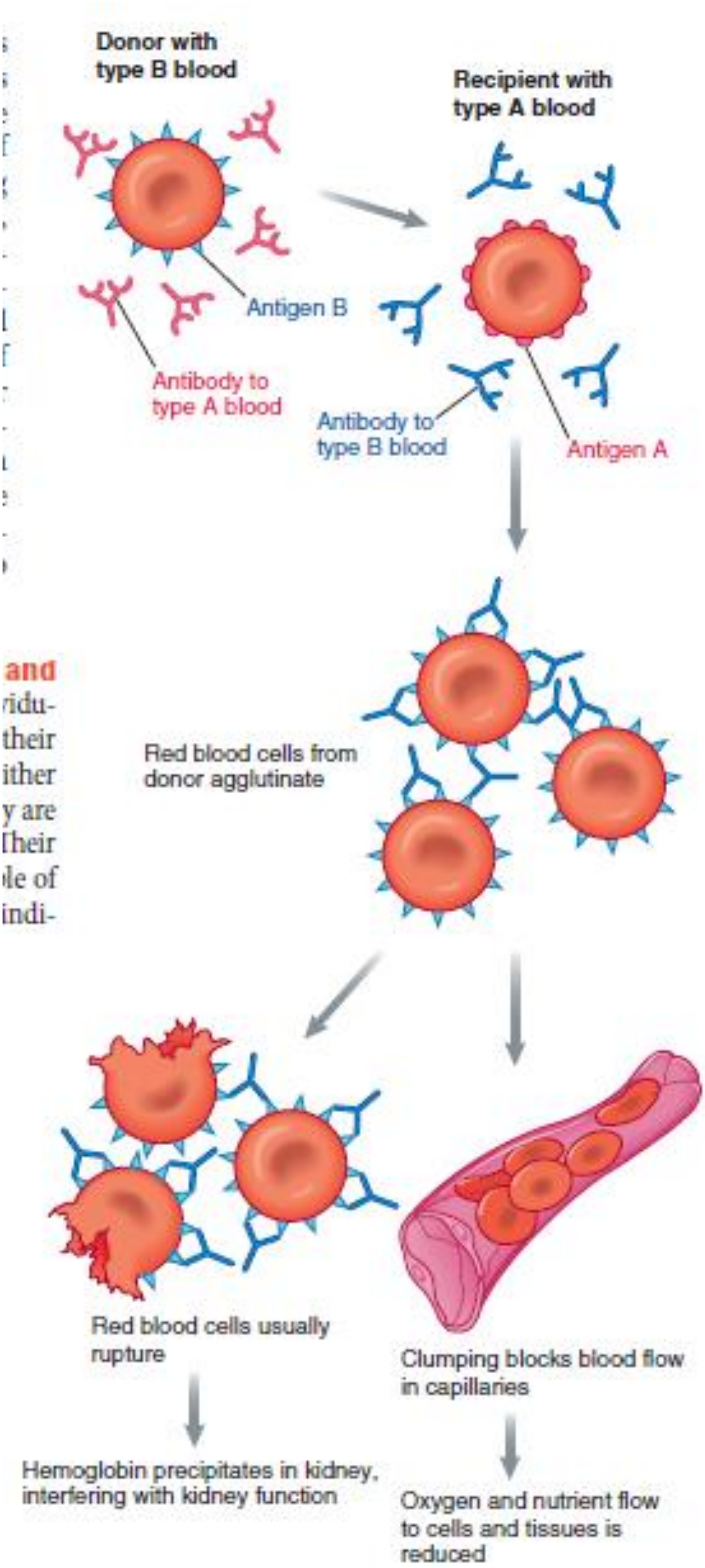
In contrast to the ABO system, no naturally occurring antibodies develop against the Rh factor. Anti-Rh antibodies are produced only by Rh-negative individuals when (and if) such people are first exposed to the foreign Rh antigen present in Rh positive blood.

Rh positive individuals, in contrast, never produce antibodies against the Rh factor that they themselves possess.

Therefore, Rh-negative people should be given only Rh-negative blood, whereas Rh-positive people can safely receive either Rh- negative or Rh-positive blood.

The Rh factor is of particular medical importance when an Rh-negative mother develops antibodies against the erythrocytes of an Rh-positive fetus she is carrying, a condition known as **erythroblastosis fetalis**, or **hemolytic disease of the newborn**. Because the maternal antibodies destroy many fetal RBCs.

Except in extreme emergencies, it is safest to individually cross-match blood before a transfusion is undertaken even though the ABO and Rh typing is already known, because there are approximately 23 other minor human erythrocyte antigen systems, with hundreds of subtypes. Compatibility is determined by mixing the RBCs from the potential donor with plasma from the recipient. If no clumping occurs, the blood is considered an adequate match for transfusion.


Donor with type B blood
Recipient with type A blood
Antigen B
Antibody to type A blood
Antibody to type B blood
Antigen A
Red blood cells from donor agglutinate
Red blood cells usually rupture
Clumping blocks blood flow in capillaries
Hemoglobin precipitates in kidney, interfering with kidney function
Oxygen and nutrient flow to cells and tissues is reduced