Department of biology

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animal physiology

Stage (-3-)

LEC- ((4))

Blood physiology

By

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Blood physiology

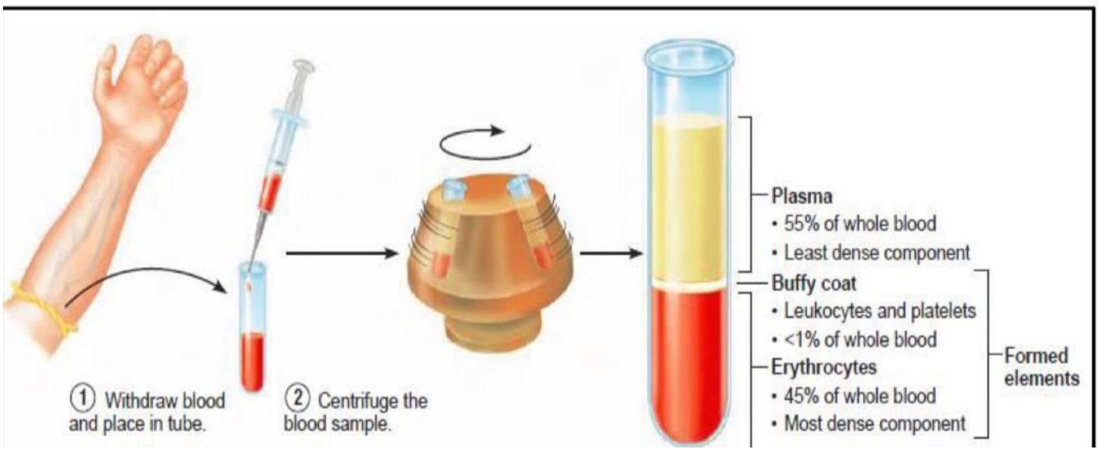
Blood is a specialized type of connective tissue in which living blood cells, called the formed elements, are suspended in a nonliving fluid matrix called plasma. The collagen and elastic fibers typical of other connective tissues are absent from blood, but dissolved fibrous proteins become visible as fibrin strands during blood clotting. Blood is a tissue present in the circulatory system. It is a red in color due to presence of hemoglobin .

Blood is made up of :

1 Fluid component: **Plasma**

2 -Formed elements: **Erythrocytes (RBCs), Leukocytes (WBCs), and Thrombocytes (Platelets) .**

Plasma constitutes **55%** of blood and formed elements constitute **45%.**



Physical Characteristics and Volume

Blood is a sticky, opaque fluid with a characteristic metallic taste.

Depending on the amount of oxygen it is carrying, the color of blood varies from scarlet (**oxygen rich**) to dark red (**oxygen poor**) .

Blood is more dense than water and about five times more viscous, largely because of its formed elements. Blood is slightly alkaline with a pH between (7.35 and 7.45) and its temperature (**38 C**) is always slightly higher than body temperature. Blood accounts for approximately 8% of body weight. Its average volume in healthy adult males is **5-6** L, somewhat greater than in healthy adult females **4-5** L .

Functions

Blood performs several functions, all concerned in one way or another with distributing substances, regulating blood levels of particular substances, or protecting the body .

Distribution

Distribution functions of blood include

- Delivering **oxygen** from the lungs and nutrients from the digestive tract to all body cells .
- Transporting **metabolic waste** products from cells to elimination sites (to the lungs for elimination of carbon dioxide, and to the kidneys for disposal of nitrogenous wastes in urine.
- Transporting **hormones** from the endocrine organs to their target organs .

Regulation

Regulatory functions of blood include

1 -Maintaining appropriate **body temperature** by absorbing and distributing heat throughout the body and to the skin surface to encourage heat loss .

2 -Maintaining **normal pH** in body tissues. Many blood proteins act as buffers to prevent excessive or abrupt changes in blood pH that could affect normal cell activities .

3 -Maintaining adequate fluid **volume** in the circulatory system.

Salts (sodium chloride and others) and blood proteins act to prevent excessive fluid loss from the bloodstream into the tissue spaces.

Protection

Protective functions of blood include

- Preventing blood loss. When a blood vessel is damaged, platelets and plasma proteins initiate clot formation, halting blood loss .
- Preventing infection. Blood contains antibodies, complement proteins, and white blood cells, all of which help defend the body against foreign invaders such as bacteria and viruses .

Plasma

Blood plasma is a straw-colored, sticky fluid. Although it is mostly water (about **90%**), plasma contains over 100 different dissolved solutes, including nutrients, gases, hormones, wastes and products of cell activity, ions, and proteins .

Plasma proteins are the most abundant solutes in plasma. Except for Antibodies and protein-based hormones, the liver makes most plasma proteins .

1 **Albumin:** Accounts for some **60%** of plasma protein, produced by liver. It acts as a carrier to transport certain molecules through the circulation like bilirubin , hormones, and drugs. It is the major blood protein contributing to the plasma osmotic pressure (the pressure that helps to keep water in the bloodstream) .

2 **Fibrinogen**: A coagulation protein, accounts for some **4%** of plasma proteins ; produced by liver; forms fibrin threads of blood clot .

3 **Globin**: **36%** of plasma proteins, including :

A- **alpha and beta**, which produced by liver; most are transport proteins that bind to lipids, metal ions, and fat-soluble vitamins .

B- **Gamma**: Antibodies released by plasma cells during immune response .

4 **Prothrombin**: Is the inactive precursor of thrombin. The normal concentration in plasma is 15 mg/ dL, it is formed in the liver with the

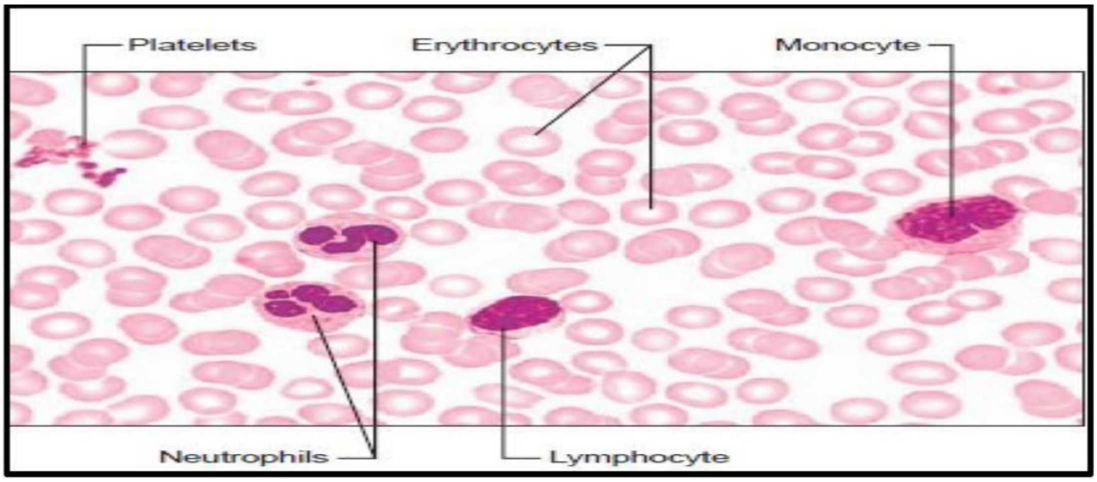
help of vitamin K.

Formed Elements of blood

There are, **erythrocytes**, **leukocytes**, and **platelets**, have some unusual features :

1. Two of the three are not even true cells: Erythrocytes have no nuclei or organelles, and platelets are cell fragments. Only leukocytes are complete cells .
2. Most of the formed elements survive in the bloodstream for only a few days .
3. Most blood cells do not divide. Instead, they are continuously renewed by division of cells in red bone marrow, where they originate .

If you examine a stained smear of human blood under the light microscope , you will see disc-shaped red blood cells, stained spherical white blood cells, and some scattered platelets that look like debris. Erythrocytes vastly outnumber the other types of formed elements.



Red blood cell (erythrocyte):

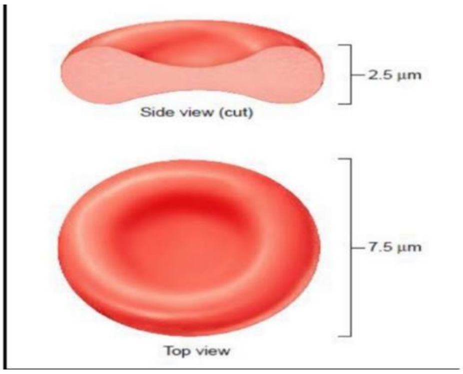
Structural Characteristics

Erythrocytes or red blood cells (RBCs) are small cells, about 7.5 µm in diameter. Shaped like biconcave discs—flattened discs with depressed centers—they appear lighter in color at their thin centers than at their edges .

Red blood cells lose nuclei upon maturation and have essentially no organelles. RBC's live about 120 days and do not self-repair. RBC's contain hemoglobin, which transports oxygen. The hemoglobin gets its red color from their respiratory pigments. In fact, RBCs are little more than "bags" of hemoglobin (Hb), the RBC protein that functions in gas transport .

Other proteins are present, such as antioxidant enzymes that rid the body of harmful oxygen radicals, but most function mainly to maintain the plasma membrane or promote changes in RBC shape. For example, the biconcave shape of an erythrocyte is maintained by a network of proteins, especially one called spectrin, attached to the cytoplasmic face of its plasma membrane. The spectrin net is deformable, giving erythrocytes flexibility to change shape as necessary .

Women typically have a lower red blood cell count than men **(4.3–5.2)** million cells per microliter (1 µl = 1 mm3) of blood versus **(5.1–5.8)** million cells/µl respectively.

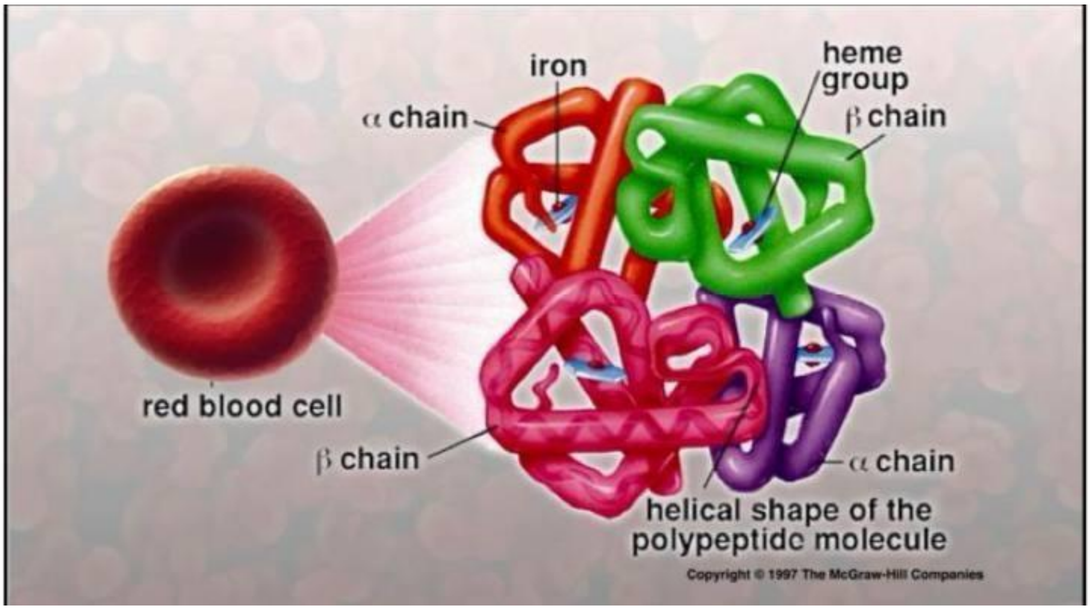


Function

Erythrocytes are completely dedicated to their job of transporting respiratory gases (oxygen and carbon dioxide). Hemoglobin, the protein that makes red blood cells red, binds easily and reversibly with oxygen, and most oxygen carried in blood is bound to hemoglobin. Normal values for hemoglobin are **14–20** grams per 100 milliliters of blood (g/100 ml) **in infants, 13–18** g/100 ml in **adult males** and **12–16** g/100 .ml in **adult females**.

Hemoglobin is made up of the protein globin bound to the red heme pigment.

Globin consists of four polypeptide chains—**two alpha and two beta** each binding a ring like heme group. Each heme group bears an atom of iron set like a jewel in its center. A hemoglobin molecule can transport four molecules of oxygen because each iron atom can combine reversibly with one molecule of oxygen A single red blood cell contains about **250** million hemoglobin molecules so each of these tiny cells can scoop up about 1 billion molecules of oxygen.



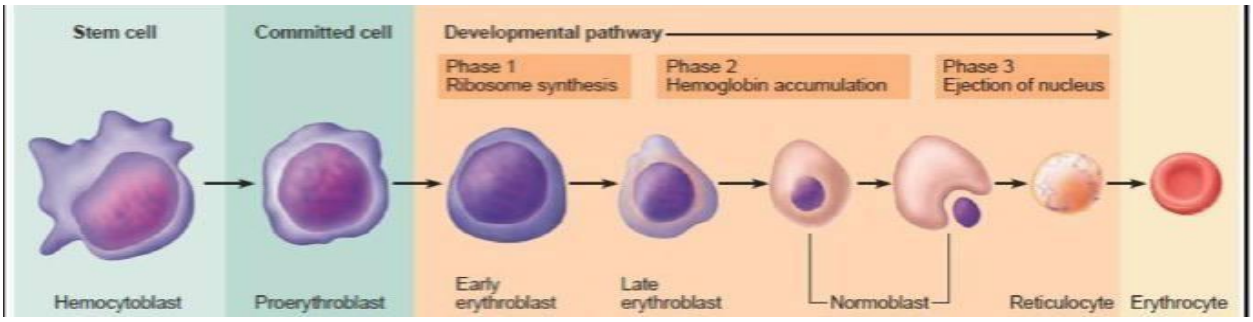
Production of Erythrocytes

Blood cell formation is referred to as hematopoiesis, or hemopoiesis. This process occurs in the red bone marrow **(myeloid tissue),** which is composed largely of a soft network of reticular connective tissue bordering on wide blood capillaries called blood sinusoids, although when the body is under severe conditions the yellow bone marrow, which is also in the fatty places of the marrow in the body will also make .RBC's. The formation of RBC's is called **erythropoiesis**

Each type of blood cell is produced in different numbers in response to changing body needs and different regulatory factors. As blood cells mature, they migrate through the thin walls of the sinusoids to enter the bloodstream.

On average, the marrow turns out an ounce of new blood containing some 100 billion new cells each and every day. All arise from the same type of stem cell, the hemocytoblast.

additionally, its nuclear functions end and its nucleus degenerates and is pinched off, allowing the cell to collapse inward and eventually assume the biconcave shape.



The entire process from hemocytoblast to reticulocyte takes about 15 days.

The reticulocytes, filled almost to bursting with hemoglobin, enter the bloodstream to begin their task of oxygen transport. Usually they become fully mature erythrocytes within two days of release as their ribosomes

.are degraded by intracellular enzymes.

Reticulocytes account for 1–2% of all erythrocytes in the blood of healthy people. Reticulocyte counts provide a rough index of the rate of RBC formation.

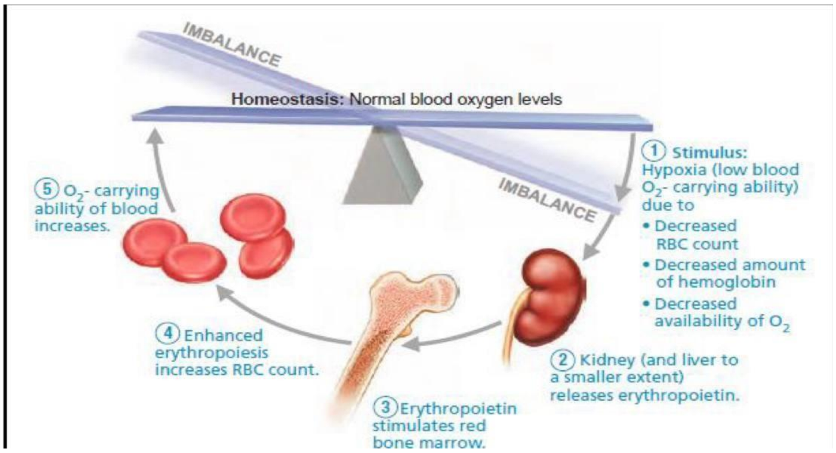
If this counts below or above this percentage range indicate abnormal rates of erythrocyte formation.

Regulation and Requirements for Erythropoiesis

The number of circulating erythrocytes in each individual is remarkably constant and reflects a balance between red blood cell production and destruction. This balance is important because having too few erythrocytes leads to tissue hypoxia **(oxygen deprivation),** whereas having too many makes the blood undesirably viscous. To ensure that the number of erythrocytes in blood remains within the homeostatic range, new cells are produced at the incredibly rapid rate of more than 2 million per second in healthy people. This process is controlled hormonally and

.depends on adequate supplies of **iron, amino acids and certain B vitamins**

Hormonal Controls The direct stimulus for erythrocyte formation is provided by **erythropoietin (EPO),** a glycoprotein hormone. Normally, a small amount of EPO always circulates in the blood and sustains red blood cell production at a basal rate. The kidneys play the major role in EPO production, although the liver produces some. When certain kidney cells become hypoxic (i.e., have inadequate oxygen), it accelerates the synthesis and release of **erythropoietin.**



Dietary Requirements

The raw materials required for erythropoiesis include the usual nutrients and structural materials— **amino acids, lipids, and carbohydrates**.

Iron is essential for hemoglobin synthesis. Iron is available from the diet, and its absorption into the bloodstream is precisely controlled by intestinal cells in response to changing body stores of iron.

Approximately **65%** of the body's iron supply is in hemoglobin.

Most of the remainder is stored in the liver, spleen, and bone marrow. Free iron ions (Fe^{2+},Fe^{3+}) are toxic, so iron is stored inside cells as .protein iron complexes such as **ferritin** and **hemosiderin**

Two **B-complex vitamins**—**vitamin B12 and folic acid**—are necessary for normal **DNA synthesis**. .dividing cell populations, such as developing erythrocytes

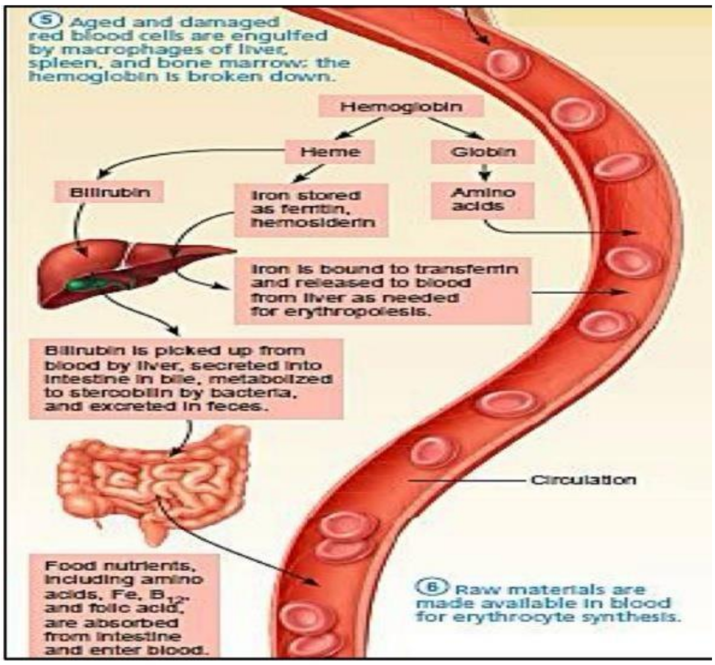
Fate and Destruction of Erythrocytes

Red blood cells have a useful life span of **100 to 120 days.** Their **anucleate condition** carries with it some important limitations. Red blood cells are unable to synthesize new proteins, to grow, or to divide.

Erythrocytes become “old” as they lose their flexibility and become increasingly rigid and fragile, and their contained hemoglobin begins to degenerate.

Dying erythrocytes are engulfed and destroyed by macrophages of spleen liver and bone marrow

The heme of their hemoglobin is split off from globin. Its core of iron is salvaged, bound to protein **(as ferritin or hemosiderin)**, and stored for reuse in **bone marrow**.



Leukocytes

(leuko = white), or white blood cells **(WBCs),** are the only formed .elements that are complete cells, with nuclei and the usual organelles

Accounting for less than **1%** of total blood volume. On average, there are **4800 -10,800** WBCs/mm3 of blood .

Leukocytes are crucial to our defense against disease. They form a mobile army that helps protect the body from damage by bacteria, viruses, parasites toxins, and tumor cells. As such, they have some special functional characteristics. Red blood cells are confined to the bloodstream, and they carry out their functions in the blood, but white blood cells are able to slip out of the capillary blood vessels- a process called diapedesis. Once out of the bloodstream, leukocytes move through the tissue spaces by amoeboid motion by following the chemical trail of molecules released by damaged cells or other leukocytes, a phenomenon called positive chemotaxis, they can pinpoint areas of tissue damage and infection and gather there in large numbers to destroy foreign substances or dead cells. Leukocytes are grouped into two major categories on the basis of structural and chemical characteristics.

Granulocytes contain obvious membrane-bound cytoplasmic granules, and **agranulocytes** lack obvious granules

Granulocytes

Granulocytes, which include neutrophils, basophils, and eosinophils, are .spherical in shape, have lobed nuclei. They are larger than erythrocytes

Neutrophils: are the most numerous of the white blood cells, accounting of the WBC population. The neutrophil cytoplasm stains for **50-70%** pale lilac and contains very fine granules. Some of these granules contain hydrolytic enzymes and are regarded as lysosomes. Others, especially the

.smaller granules, contain potent antimicrobial proteins, called defensins

Eosinophils: account for **2-4%** of all leukocytes. Large, coarse granules contain digestive enzymes. The most important role of eosinophils is to lead the counter attack against parasitic worms that are too large to be phagocytized.

Eosinophils have complex roles in many other diseases including allergy and asthma.

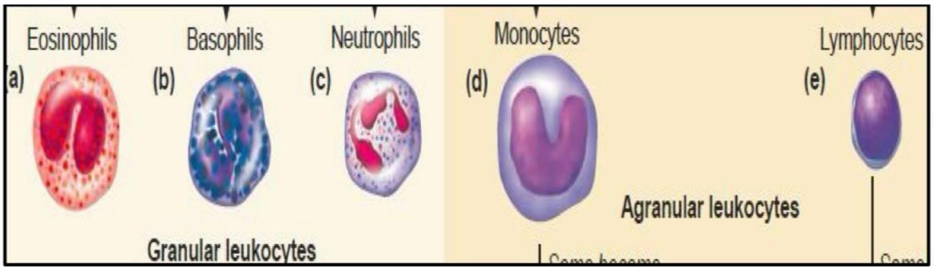
Basophils: are the rarest white blood cells, averaging only **0-1%** of the leukocyte population. The deep purple nucleus is generally U or S shaped. Their cytoplasm contains large, coarse, histamine-containing granules that have an affinity for the basic dyes. **Histamine** is an inflammatory chemical that acts as a vasodilator (makes blood vessels dilate) and attracts other white blood cells to the inflamed site; drugs called antihistamines counter this effect.

Agranulocytes

The agranulocytes include lymphocytes and monocytes, **WBCs** that lack visible cytoplasmic granules. Their nuclei are typically spherical or kidney shaped.

Lymphocytes: accounting for 25%. Lymphocytes are closely associated with lymphoid tissues (lymph nodes, spleen), where they play a crucial role in immunity. T lymphocytes **(T cells)** function in the immune response by acting directly against virus-infected cells and tumor cells, it is processed in the thymus gland. B-lymphocytes **(B cells)** give rise to plasma cells, which produce antibodies that are released to the blood. They are processed in fetal liver and bone marrow in human

Monocytes: account for **3–8%** of **WBCs**. When circulating monocytes leave the bloodstream and enter the tissues, they differentiate into highly mobile macrophages. Macrophages are actively phagocytic, and they are crucial in the body's defense against viruses, certain intracellular bacterial parasites, and chronic infections such as tuberculosis, macrophages are also important in activating lymphocytes to mount the immune response.



Platelets

Platelets are cytoplasmic fragments of extraordinarily large cells called megakaryocytes. In blood smears, each platelet exhibits a blue-staining outer region and an inner area containing granules that stain purple. The granules contain an impressive array of chemicals that act in the clotting process including **serotonin, Ca2+, a variety of enzymes, ADP, and platelet-derived growth factor (PDGF).** Platelets are essential for the clotting process that occurs in plasma when blood vessels are ruptured or their lining is injured. Platelets age quickly because they are a-nucleate, and they degenerate in about **10 days** if they are not involved in clotting.