
Body Fluids and Circulation - Part 1

Objective

After going through this lesson, the learners will be able to understand the following:

- Different types of body fluids in human beings
- Plasma and blood
- Formed elements of blood
- Functions of blood

Content Outline

- Introduction
- Body Fluids
- Blood
- Formed elements
 - RBCs
 - WBCs
 - Platelets
- Plasma
- Functions of blood
- Summary

Introduction

Every living organism constantly needs the exchange of substances such as nutrients, waste products, and respiratory gases with the environment in order to survive and grow. The exchange of substances between the organism and its environment usually takes place through diffusion. The exchange of substances occurs rapidly if -

- (a) The surface area of the organism in contact with the environment is large.
- (b) The volume of the organism is small.
- (c) The total surface area/volume ratio of the organism is large.
- (d) The distance between the source of the substances and the body cells is near.
- (e) A high concentration gradient is maintained between the source and the body cell.

The human circulatory system functions to transport blood and oxygen from the lungs to the various tissues of the body. The heart pumps the blood throughout the body. The lymphatic

system is an extension of the human circulatory system that includes cell-mediated and antibody-mediated immune systems. The components of the human circulatory system include the heart, blood, red and white blood cells, platelets, and the lymphatic system.

Body Fluids

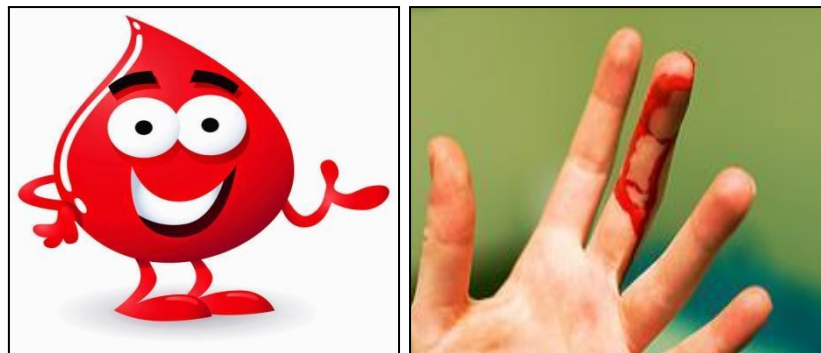
Body fluid, bodily fluids or bio-fluids are liquids originating from inside the bodies of living people. They include fluids that are excreted or secreted from the body, and body water that normally is not. The dominating content of body fluids is body water. In humans approximately 60-65% of body water is contained within the cells (in intracellular fluid) with the other 35-40% of body water contained outside the cells (in extracellular fluid). This fluid component outside the cells includes the fluid between the cells (interstitial fluid), lymph and blood. There are approximately 6 to 10 liters of lymph in the body, compared to 3.5 to 5 liters of blood.

The following is a list of some body fluids found in our body:

- **Amniotic fluid:** It is the protective liquid contained by the amniotic sac of a gravid Amniote. This fluid serves as a cushion for the growing fetus, but also serves to facilitate the exchange of nutrients, water, and biochemical products between mother and fetus.
- **Aqueous humour:** It is a transparent, watery fluid which fills both the anterior and the posterior chambers of the eye.
- **Bile or gall** is a dark green to yellowish brown fluid, produced by the liver of most vertebrates, that aids the digestion of lipids in the small intestine.
- **Blood:** Blood plays a major role in the body's defense against infection by carrying waste away from our cells and flushing them out of the body in urine, feces, and sweat. Blood also supplies the body with essential substances such as hormones, sugar, and oxygen that the body needs to function and survive.
- **Breast milk** is the milk produced by the breasts (or mammary glands) of a human female to feed a child. Milk is the primary source of nutrition for newborns before they are able to eat and digest other foods.
- **Cerebrospinal fluid (CSF)** is a clear, colorless body fluid found in the brain and spinal cord. It acts as a cushion or buffer for the brain.

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- **Earwax** is a yellowish waxy substance secreted in the ear canal of humans and other mammals. It protects the skin of the human ear canal, assists in cleaning and lubrication, and also provides some protection against bacteria, fungi, insects and water.
 - **Chyme** is the semi-fluid mass of partly digested food that is expelled by the stomach, through the pyloric valve, into the duodenum (the beginning of the small intestine). Chyme results from the mechanical and chemical breakdown of a bolus and consists of partially digested food, water, hydrochloric acid, and various digestive enzymes.
 - **Gastric juice** or **stomach acid**, is a digestive fluid formed in the stomach and is composed of hydrochloric acid (HCl), potassium chloride (KCl) and sodium chloride (NaCl). The acid plays a key role in digestion of proteins, by activating digestive enzymes.
 - **Lymph** is an extra cellular fluid that circulates throughout the lymphatic system. It is formed when the interstitial fluid is collected through lymph capillaries. It is then transported through larger lymphatic vessels to lymph nodes, where it is cleaned by lymphocytes, before it mixes back with the blood.
 - **Mucus** is a slippery aqueous secretion produced from cells found in mucous glands. It is a viscous colloid containing inorganic salts and some antiseptic enzymes. Mucus serves to protect epithelial cells in the respiratory, gastrointestinal, urogenital, visual, and auditory systems, against infectious agents such as fungi, bacteria and viruses.
 - **Pus** is an exudate, typically white-yellow, yellow, or yellow-brown, formed at the site of inflammation during bacterial or fungal infection. Pus consists of a thin, protein-rich fluid, known as *liquor puris*, and dead leukocytes (mostly neutrophils). As the neutrophils die off from toxins and old age, they are destroyed by macrophages, forming the viscous pus.
 - **Saliva** is a watery substance secreted by the salivary glands. The enzymes found in saliva are essential in beginning the process of digestion of dietary starches and fats. It serves a lubricative function, wetting food and permitting the initiation of swallowing, and protecting the mucosal surfaces of the oral cavity from desiccation.
 - **Semen**, also known as **seminal fluid**, is an organic fluid that is released in males during ejaculation and may contain spermatozoa, protein, fructose and can fertilize female ova. It provides a medium through which spermatozoa can move or "swim".
 - **Sweat** is the production of fluids secreted by the sweat glands in the skin of mammals.
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- **Tears** serve to clean and lubricate the eyes in response to an irritation of the eyes. Tears formed through crying are associated with strong internal emotions, such as elation, love, awe, sorrow, and pleasure etc. Laughing or yawning may also lead to the production of tears.
 - **Urine** is made up of 95% water and other nitrogenous wastes. It flushes out chemicals and dead blood cells from the body and is a way for our body to get rid of extra water that it does not need.
 - **Vaginal fluids** are biological fluids that are within or expelled from the vagina and contain carbohydrates, amino acids, proteins, and other acids produced by the normal lactobacillus bacteria.
 - **Vitreous humour:** It is the clear gel that fills the space between the lens and the retina of the eyeball of humans and other vertebrates.
 - **Vomiting** is the involuntary, forceful expulsion of the contents of one's stomach through the mouth and sometimes the nose.



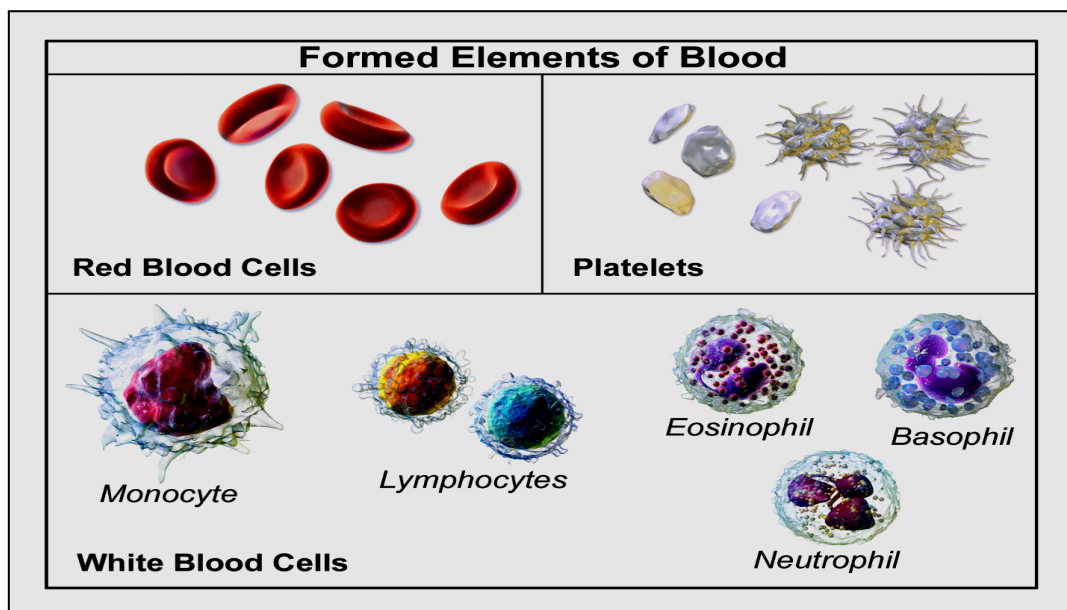
Blood

Blood is a body fluid in humans and other animals that delivers necessary substances such as nutrients and oxygen to the cells and transports metabolic waste products away from those same cells. In vertebrates, it is composed of blood cells suspended in blood plasma. Plasma, which constitutes 55% of blood fluid, is mostly water (92% by volume), and contains dissolved proteins, glucose, mineral ions, hormones, carbon dioxide (plasma being the main medium for excretory product transportation), and blood cells themselves. Albumin is the main protein in plasma, and it functions to regulate the colloidal osmotic pressure of blood. The blood cells are mainly red blood cells (also called **RBCs** or **erythrocytes**), **white blood cells** (also called **WBCs** or **leukocytes**) and **platelets** (also called **thrombocytes**). The most abundant cells in vertebrate blood are red blood cells. These contain hemoglobin, an

iron-containing protein, which facilitates oxygen transport by reversibly binding to this respiratory gas and greatly increasing its solubility in blood. In contrast, carbon dioxide is mostly transported extracellularly as bicarbonate ion transported in plasma. Blood forms about 6-10% (average 7-8%) of the body weight. The volume of blood in an adult person is about 6.8 litres. Vertebrate blood is bright red when its hemoglobin is oxygenated and dark red when it is deoxygenated. Some animals, such as crustaceans and mollusks, use hemocyanin to carry oxygen, instead of hemoglobin. Insects and some mollusks use a fluid called hemolymph instead of blood, the difference being that hemolymph is not contained in a closed circulatory system. The blood is formed of two parts: (a) Plasma (b) Formed elements.

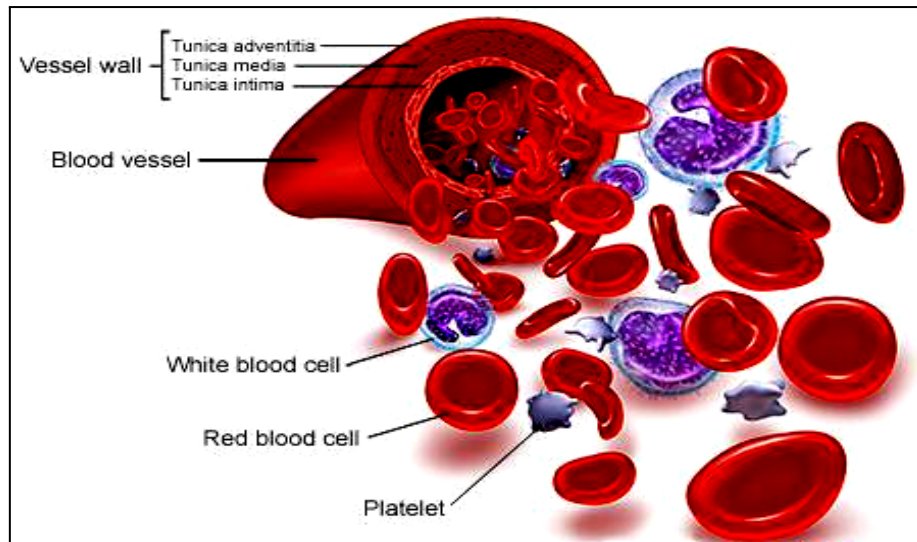
Formed Elements

The formed elements are so named because they are enclosed in a plasma membrane and have a definite structure and shape. All formed elements are cells except for the platelets, which are tiny fragments of bone marrow cells.



Formed elements are:

- Erythrocytes, also known as red blood cells (RBCs)
- Leukocytes, also known as white blood cells (WBCs)
- Platelets



Source: <https://www.myvmc.com/anatomy/blood-function-and-composition>

- **Red Blood Cells (RBCs)**

Structure: The red blood cells are also known as **erythrocytes** and these are the most predominant cells in the blood. An erythrocyte is a disc-shaped cell with a thick rim and a thin sunken centre. The plasma membrane of a mature RBC has glycoproteins and glycolipids that determine a person's blood type. On its inner surface are two proteins called spectrin and actin that give the membrane resilience and durability. This allows the RBCs to stretch, bend and fold as they squeeze through small blood vessels, and to spring back to their original shape as they pass through larger vessels.



Normal RBCs

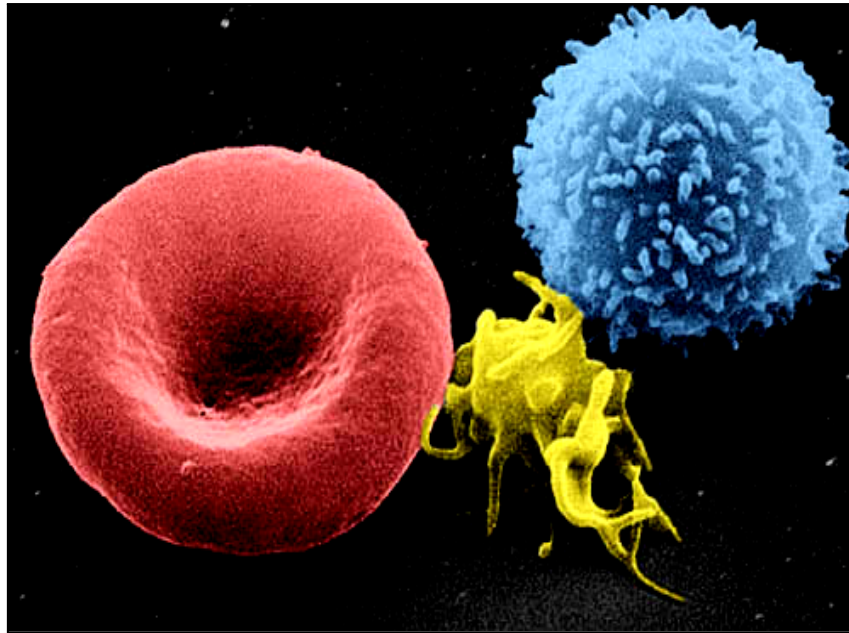
RBCs are incapable of aerobic respiration, preventing them from consuming the oxygen they transport because they lose nearly all their inner cellular components during maturation. The inner cellular components lost include their mitochondria, which normally provide energy to a cell, and their nucleus, which contains the genetic material of the cell and enables it to

repair itself. The lack of a nucleus means that RBCs are unable to repair themselves. However, the resulting biconcave shape is that the cell has a greater ratio of surface area to volume, enabling O₂ and CO₂ to diffuse quickly to and from Hb (haemoglobin). The cytoplasm of a RBC consists mainly of a 33% solution of haemoglobin (Hb). Each erythrocyte contains approximately 280 million hemoglobin molecules, which give blood its red color. A healthy individual has 12-16 gm of haemoglobin in every 100 ml of blood. Each hemoglobin molecule consists of four protein chains called globins, each of which is bound to one heme, a red-pigmented molecule that contains iron. The iron group of heme is able to combine with oxygen in the lungs and release oxygen in the tissues.

Life Span: Circulating erythrocytes live for about 120 days. As a RBC ages, its membrane grows increasingly fragile. Without key organelles such as a nucleus or ribosomes, RBCs cannot repair themselves, but this does not mean that we can run out of the essential cells.

Blood cells are constantly reproduced within the bone marrow and this means that the body constantly has fresh blood supply. The fact that the body is always reproducing blood makes it safe for us to donate our blood as long as we are healthy. Older erythrocytes are removed from the circulation by phagocytic cells in the liver, spleen, and bone marrow. Many RBCs die in the spleen, where they become trapped in narrow channels, broken up and destroyed. The Hb is then further broken down into its different components and either recycled in the body for further use or disposed of.

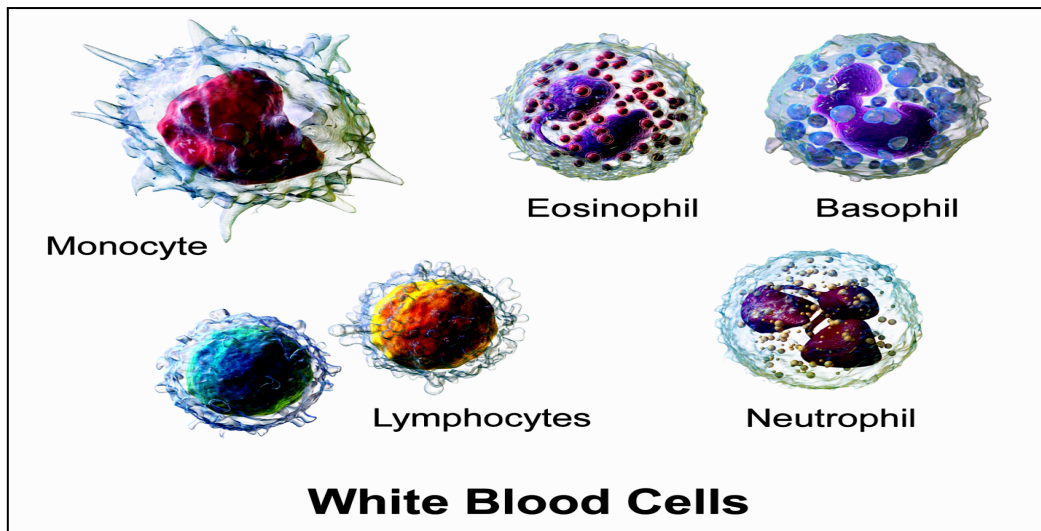
Normal Count: There are millions of red blood cells found in a single drop of blood. Men are estimated to have more blood cells than women and their count ranges between 4.7 and 6.1 million cells per microliter (cells/mcL). In women, the count ranges between 4.2 million and 5.4 million cells per microliter (cells/mcL).



- **White Blood Cells (WBCs)**

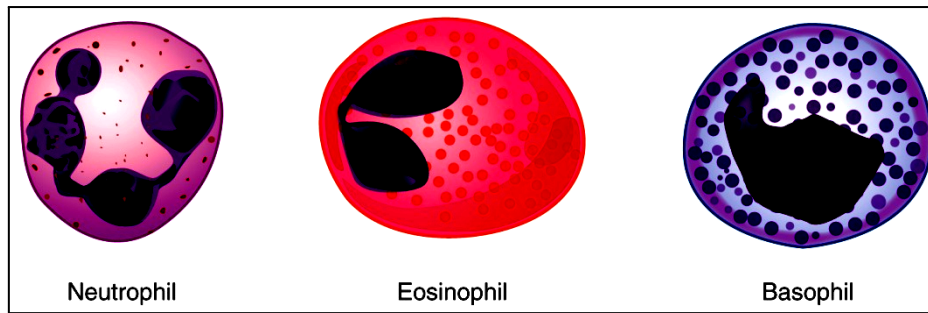
White blood cells (WBCs) are also known as **leukocytes**. Leukocytes differ from erythrocytes in several respects. Leukocytes contain nuclei and mitochondria and can move in an amoeboid fashion. Because of their amoeboid ability, leukocytes can squeeze through pores in capillary walls and move to a site of infection, whereas erythrocytes usually remain confined within blood vessels. They are relatively lesser in number, which averages $6000-8000 \text{ mm}^{-3}$.

White blood cells are almost invisible under the microscope unless they are stained; therefore, they are classified according to their staining properties. Those leukocytes that have granules in their cytoplasm are called granular leukocytes or **granulocytes** and those without clearly visible granules are called agranular leukocytes or **agranulocytes**. The former have cytoplasm that contains organelles that appear as coloured granules through light microscopy, hence their name. Granulocytes consist of neutrophils, eosinophils and basophils. In contrast, agranulocytes do not contain granules. They consist of lymphocytes and monocytes.



- **Granulocytes**

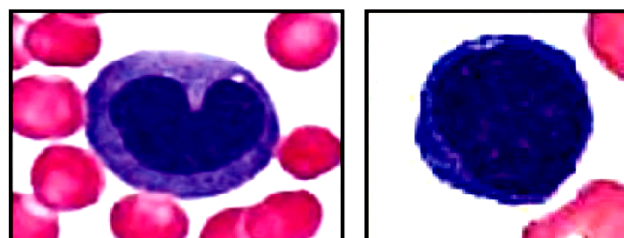
- **Neutrophils:** These contain very fine cytoplasmic granules that can be seen under a light microscope. Neutrophils are also called polymorphonuclear (PMN) because they have a variety of nuclear shapes. They play roles in the destruction of bacteria and the release of chemicals that kill or inhibit the growth of bacteria. Neutrophils are the most abundant type of leukocyte, accounting for 60% to 65% of the leukocytes in the blood.
- **Eosinophils:** These have large granules and a prominent nucleus that is divided into two lobes. They function in the destruction of allergens and inflammatory chemicals, and release enzymes that disable parasites. They are 2-3 percent of WBCs.
- **Basophils:** They have a pale nucleus that is usually hidden by granules. They secrete histamine which increases tissue blood flow via dilating the blood vessels, and also secrete histamine, serotonin and heparin which is an anticoagulant that promotes mobility of other WBCs by preventing clotting. They are the least (0.5-1 percent) of leucocytes.



Granulocytes

- **Agranulocytes**

- **Lymphocytes:** These are usually classified as small, medium or large. Medium and large lymphocytes are generally seen mainly in fibrous connective tissue and only occasionally in the circulation bloodstream. They are 20 to 30 percent of leukocytes. They are of two major types - “B” and “T” lymphocytes. Lymphocytes are responsible for immune responses of the body and help in destroying cancer cells, cells infected by viruses, and foreign invading cells. In addition, they present antigens to activate other cells of the immune system. They also coordinate the actions of other immune cells, secrete antibodies and serve in immune memory.
- **Monocytes:** They are the largest of the formed elements. Their cytoplasm tends to be abundant and relatively clear. They function in differentiating into macrophages, which are large phagocytic cells, and digest pathogens, dead neutrophils, and the debris of dead cells. Like lymphocytes, they also present antigens to activate other immune cells.



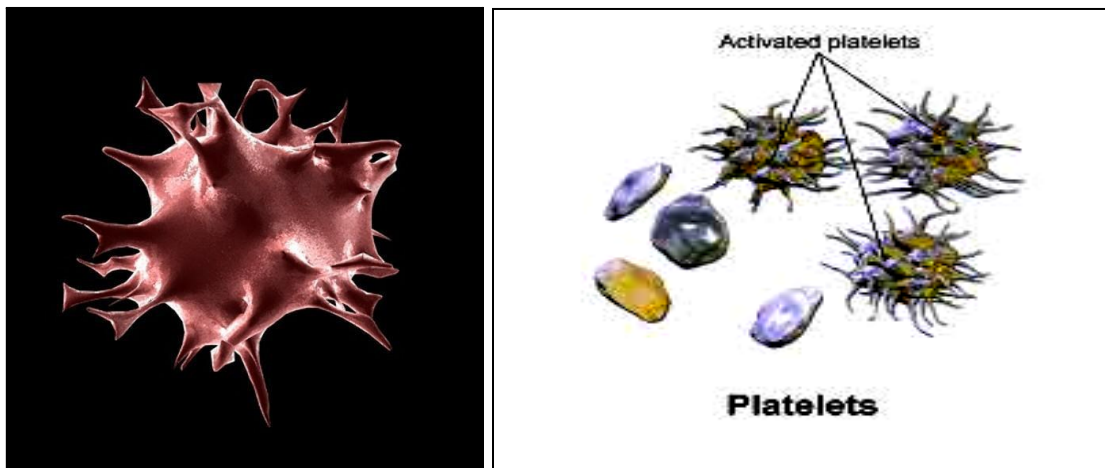
Monocyte

Lymphocyte

Normal Count: Their count is much less than that of red blood cells. A drop of blood could contain anything between 7,000 and 25,000 white blood cells. The normal white blood cell count is between 4,500 and 10,000 white blood cells per microliter (mcL).

It's important to note that having a consistent large presence of white blood cells in the blood is not a sign of good health. This could be a symptom of leukemia which is cancer of the blood. A patient suffering from leukemia would have about 50,000 white blood cells in just one drop of blood. An increase in the number of white blood cells occurs when the body has a consistent and persistent infection that fights back.

- **Blood Platelets**



Platelets or **thrombocytes** are small fragments of bone marrow cells and are therefore not really classified as cells themselves. Platelets are colourless, oval shaped, discoidal and the smallest of the formed elements and are actually fragments of large cells called megakaryocytes, which are found in bone marrow. (This is why the term formed elements is used instead of blood cells to describe erythrocytes, leukocytes, and platelets.) The fragments that enter the circulation as platelets lack nuclei but, like leukocytes, are capable of amoeboid movement. The platelet count per cubic millimeter of blood ranges from 150,000 to 350,000 mm^{-3} , but this count can vary greatly under different physiological conditions. Platelets survive for about 5 to 9 days before being destroyed by the spleen and liver.

Platelets play an important role in blood clotting. They constitute most of the mass of the clot, and phospholipids in their cell membranes activate the clotting factors in plasma that result in threads of fibrin, which reinforce the platelet plug. Platelets that attach together in a blood clot release serotonin, a chemical that stimulates constriction of the blood vessels.

Platelets have the following functions:

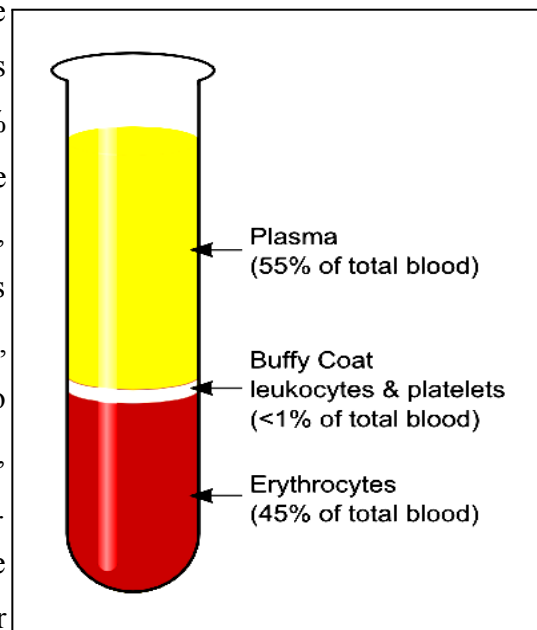
- Secrete vasoconstrictors which constrict blood vessels, causing vascular spasms in broken blood vessels
- Form temporary platelet plugs to stop bleeding
- Secrete procoagulants (clotting factors) to promote blood clotting
- Dissolve blood clots when they are no longer needed
- Digest and destroy bacteria
- Secrete chemicals that attract neutrophils and monocytes to sites of inflammation
- Secrete growth factors to maintain the linings of blood vessels

Plasma

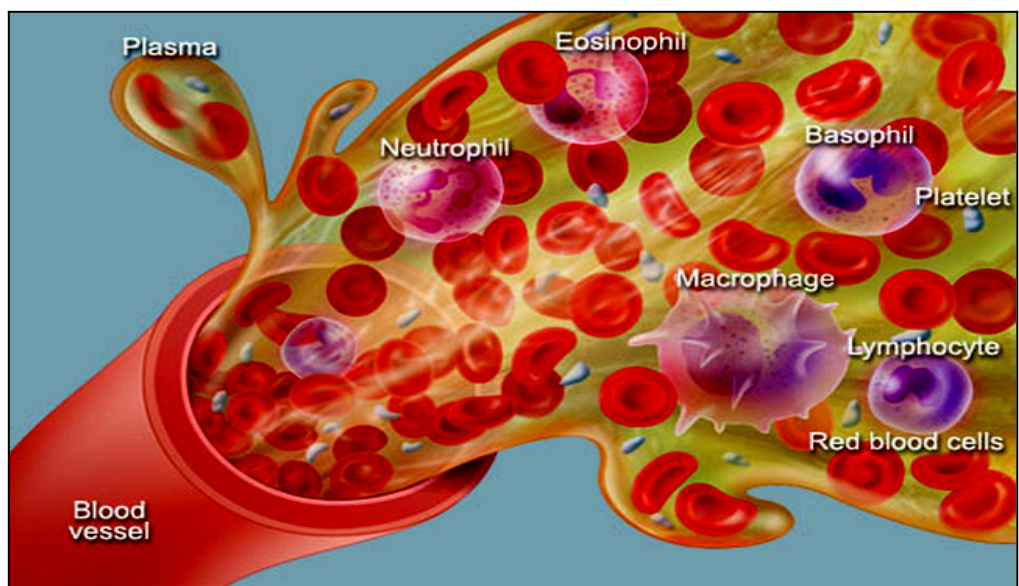
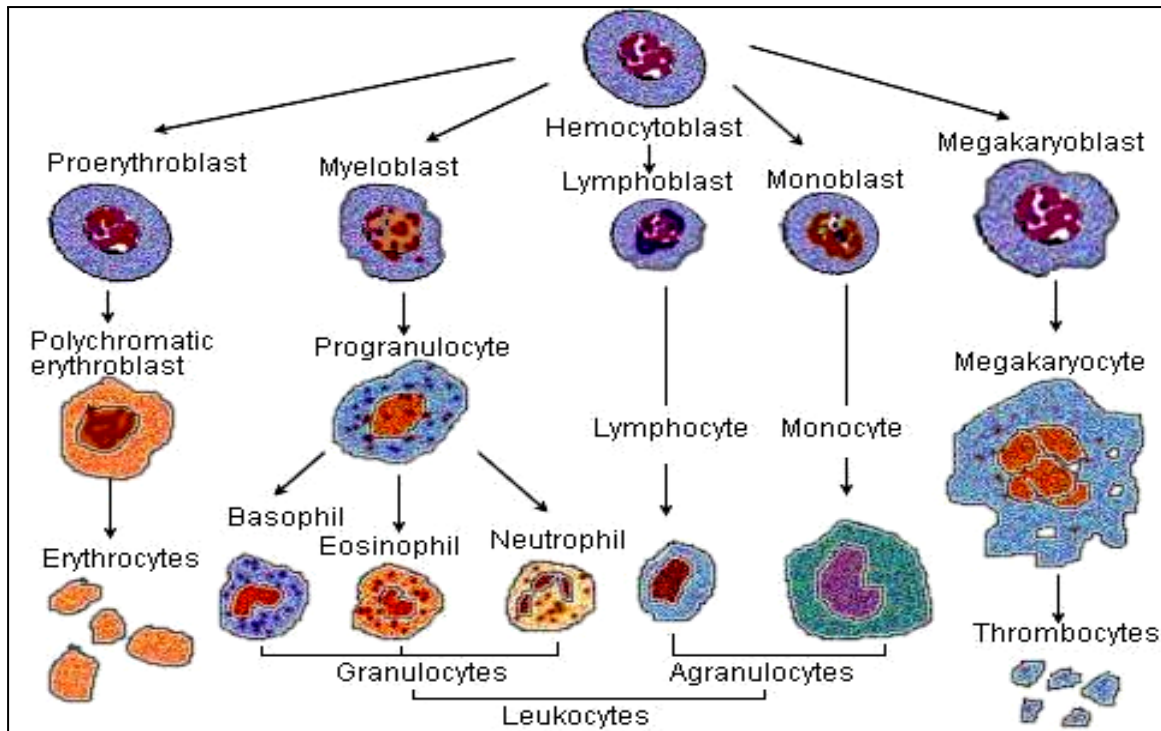
Blood plasma is a straw coloured liquid component of **blood** that normally holds the **blood** cells in whole **blood** in suspension; this makes **plasma** the extracellular matrix of **blood** cells.

It makes up about 55% of the body's total **blood** volume. The blood dust present in plasma is known as **hemoconia**. The blood plasma volume

totals 2.7-3.0 liters in an average human. It is essentially an aqueous solution containing 92% water, 8% blood plasma proteins, and trace amounts of other materials like enzymes, nutrients, wastes, hormones and gases Plasma circulates dissolved nutrients, such as glucose, amino acids, and fatty acids (dissolved in the blood or bound to plasma proteins), and removes waste products, such as carbon dioxide, urea, and lactic acid. Plasma also serves as the protein reserve of the human body. It plays a vital role in an intravascular



osmotic effect that keeps electrolytes in balanced form and protects the body from infection and other blood disorders. The term **serum** refers to plasma from which the clotting proteins have been removed. Most of the proteins remaining are albumin and immunoglobulins.



Functions of Blood

- Supply of oxygen to tissues (bound to hemoglobin, which is carried in red cells)
- Supply of nutrients such as glucose, amino acids, and fatty acids (dissolved in the blood or bound to plasma proteins (e.g., blood lipids))
- Removal of waste such as carbon dioxide, urea, and lactic acid
- Immunological functions, including circulation of white blood cells, and detection of foreign material by antibodies

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- Coagulation, the response to a broken blood vessel, the conversion of blood from a liquid to a semisolid gel to stop bleeding
 - Messenger functions, including the transport of hormones and the signaling of tissue damage
 - Regulation of core body temperature
 - Hydraulic functions

Summary

Normally, 7-8% of human body weight is from blood. In adults, this amounts to 4.5-6 Litres of blood. This essential fluid carries out the critical functions of transporting oxygen and nutrients to our cells and getting rid of carbon dioxide, ammonia, and other waste products. In addition, it plays a vital role in our immune system and in maintaining a relatively constant body temperature. Blood is a highly specialized tissue composed of more than 4,000 different kinds of components. Four of the most important ones are red cells, white cells, platelets, and plasma. All humans produce these blood components--there are no populational or regional differences. Red cells, or **erythrocytes** are relatively large microscopic cells without nuclei. They transport oxygen from the lungs to all of the living tissues of the body and carry away carbon dioxide. White cells, or **leukocytes** exist in variable numbers and types but make up a very small part of blood's volume – normally only about 1% in healthy people They seek out, identify, and bind to alien protein on bacteria, viruses, and fungi so that they can be removed. Platelets or **thrombocytes** are cell fragments without nuclei that work with blood clotting chemicals at the site of wounds. They also can release coagulating chemicals which cause clots to form in the blood that can plug up narrowed blood vessels. **Plasma** is the relatively clear, yellow-tinted water (92+%), sugar, fat, protein, and salt solution which carries the red cells, white cells, and platelets. Normally, 55% of our blood's volume is made up of plasma.