Introduction

Blood in vertebrates is a complex tissue comprising different cells that are suspended in a liquid matrix referred to as the plasma. Along with the transporting molecules, blood tends to stabilise the salt concentration and pH of the fluids in the body. It also serves as a conduit for the cells functioning in the immune system. Additionally, it is also involved in regulating the body temperature by transferring the heat between colder and warmer body regions, and between the body and the external surroundings.

The total volume of blood in an average-sized adult human is about 4 to 5 L. It accounts for about 8% of the weight of the body. A straw-coloured, clear fluid – plasma, accounts for about 55% of the blood volume in human males and 58% in females, on an average.

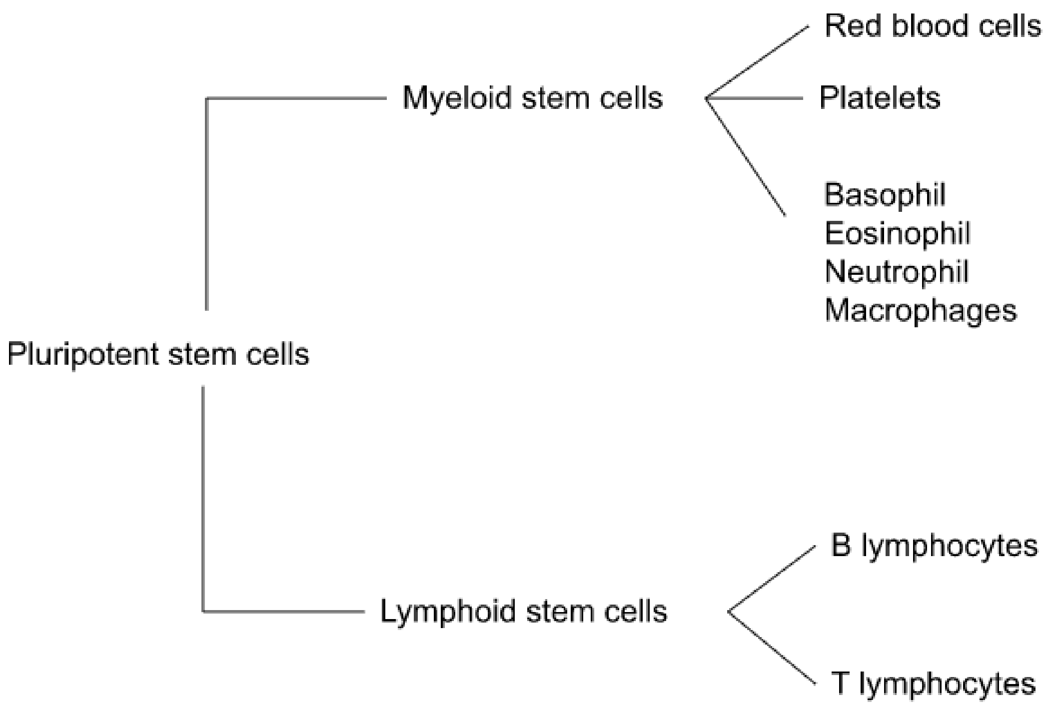
In the plasma are suspended three important types of blood cells – erythrocytes, leukocytes and the platelets. It makes up for the hematocrit – the remnants of the blood volume.

Development of Blood Cells

Blood cells in humans develop in the red bone marrow, mainly in the vertebrae, ribs, sternum and the pelvis. The blood cells take their origin from the cells referred to as pluripotent stem cells, which retain the embryonic capacity for division. These pluripotent stem cells differentiate into other two cell types – lymphoid and myeloid stem cells.

The myeloid stem cells produce the erythrocytes and platelets and 4 types of leukocytes – basophils, neutrophils, macrophages/monocytes and eosinophils. The lymphoid stem cells produce the two other types of leukocytes functioning in the immune system – T lymphocytes and B lymphocytes.

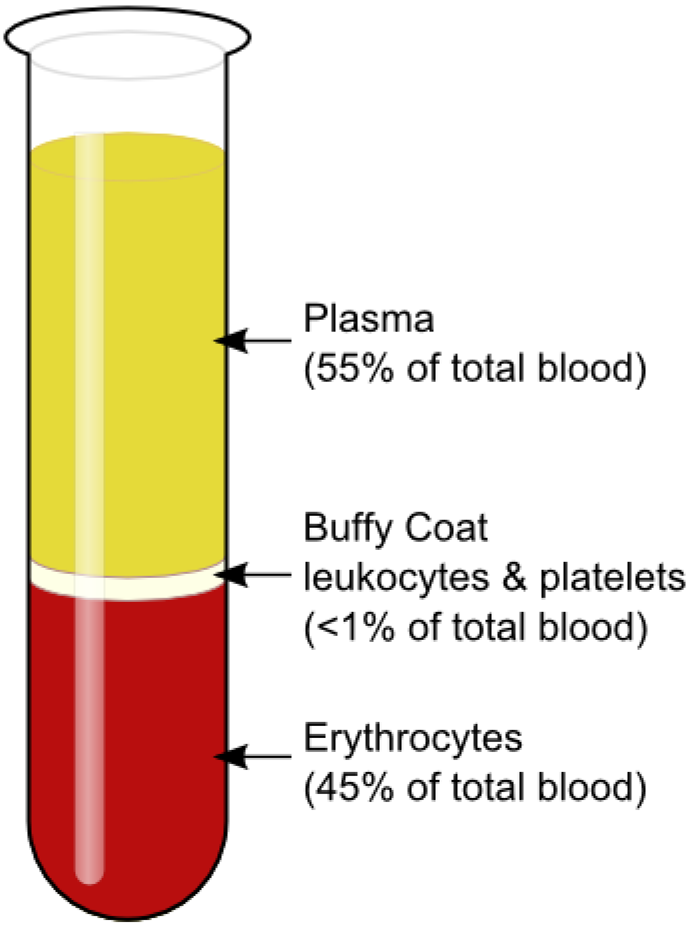
Take a look at the chart below for a better understanding-



Components of Blood and their Functions

The table below depicts the different components of blood and their functions, along with their percentage or quantity.

- Hematocrit (cellular part): Males (45%), Females (42%) of the total mass
- Plasma constituents: Males (55%), Females (58%) of the total mass



Hematocrit

Blood component	**Function**	**Cells per microlitre**
Red blood cells (erythrocytes)	Involved in the transportation of carbon dioxide and oxygen	$4.8X10^6$ – $5.4X10^6$
White blood cells (leukocytes) • Lymphocytes	Involved in immune response Phagocytosis at the time of inflammation Defensive response against parasitic worms	1000-2700 3000-6750 100-360

• Neutrophils • Eosinophils • Monocytes • Basophils	In all the defensive responses, phagocytosis Producing substances for inflammatory responses and eliminating fat from the body	150-720 25-90
Platelets	Participates in clotting	150,000 to 450,000

Plasma Constituents

Blood component	**Function**	**Plasma volume percentage**
Sugars, ions, amino acids, lipids, vitamins, hormones, dissolved gases	Participates in pH, extracellular fluid volume, etc.	1-2
Albumin, fibrinogen, globulin, etc – Plasma proteins	Transportation of lipids, clotting, defence, involved in extracellular fluid volume, etc.	7-8
Water	Serves as a solvent	91-92

Red Blood Cells (Erythrocytes)

The red blood cells (RBCs), also referred to as the erythrocytes, deliver oxygen from the lungs to different tissues of the body. There are about 5 million of these cells per microlitre of human blood. They appear as disc-like, flattened cells with indentations on each of the flattened surfaces, hence the biconcave appearance – thicker at the edges than the middle.

These cells have a diameter of about 8 mm and are 2 mm wide. RBCs are extremely flexible cells that can squeeze through the capillaries that are narrow. They are derived from the precursors found in the bone marrow, produced from the myeloid stem cells. When it matures, the mammalian RBCs lose their nuclei, ribosomes and cytoplasmic organelles, hence restricting their metabolic lifespan and capabilities. The leftover cytoplasm has the enzymes required for glycolysis, abundantly available in haemoglobin.

Most of the ATP from glycolysis is utilised to fuel active transport mechanisms which pass ions in and out of the RBCs. The protein providing RBCs with its distinct red colour is haemoglobin. It comprises 4 polypeptides in turn, each of which is associated with a non-protein heme group containing an iron atom in their centre. This atom of iron is associated with the oxygen molecules as the blood circulates through the lungs, releasing oxygen as the blood continues to flow through the different tissues of the body.

In the event when the oxygen-carrying capacity of the blood declines below the usual level, it is identified by the kidneys, which secrete the EPO (erythropoietin) hormone into the bloodstream. The hormone triggers the stem cells in the bone marrow to increase the production of the RBC. The erythropoietin hormone is also secreted after the loss of blood, and when mammals are in higher altitudes.

The oxygen-carrying capacity increases as the new erythrocytes enter the bloodstream. If this capacity increases above normalcy, the production of the hormone drops in the kidneys and production of RBCs declines. The blood groups in humans are decided by the antigens present on the surface of the erythrocytes.

White Blood Cells (Leukocytes)

The white blood cells or leukocytes remove the dying and dead cells from the body, eliminating cellular debris and defending against the invading entities. WBCs are so called as they are colourless. It retains its nuclei, ribosomes and cytoplasmic organelles as it matures, unlike the RBCs. Consequently, these cells are fully functional. While some leukocytes are produced from the precursor cells found in the bone marrow that are derived from the myeloid stem cells, others are produced from the lymphoid stem cells in the bone marrow.

Platelets

The platelets are round or oval in shape having a diameter of about 2-4 mm, and have enzymes and other factors which participate in blood clotting. These are shed from the surface of large cells in the bone marrow and are obtained from the myeloid stem cells. When the blood vessels are destroyed, the collagen fibres contained in the extracellular matrix get disclosed to the blood that is flowing out.

Then, the blood adheres to the collagen fibres, releasing signalling molecules that induce surplus platelets to cling to it. Consequently, the process is pursued which forms a plug that aids in sealing the damaged areas. With the plug formation, the platelets release other factors which convert fibrinogen into fibrin. The cross-links from the fibrin (insoluble threads) form a mesh-like network trapping the cells and platelets, thereby sealing the wounded site.

The complete mass is a clot of blood. The diseases or mutations which interfere with factors and enzymes participating in the clotting mechanism have adverse effects. It results in uncontrolled bleeding.

Plasma

Plasma forms the liquid component of blood. It is a mix of sugar, water, proteins, fats and salts. The primary function of plasma is in the transportation of the blood cells all through the body with the nutrients, antibodies, wastes, proteins of clotting, proteins and hormones that aid in maintaining the fluid balance in the body.

Important Functions of Blood

The main function of blood is to transport nutrients and oxygen and eliminate wastes from the cells of the body. The various other functions of blood are the distribution of heat, defense, and maintaining homeostasis.

Defense – Role of Blood in Defense

There are different forms of WBCs protecting from exterior threats such as the pathogenic bacteria which enter the bloodstream in a wound. Various other WBCs find and destroy the internal threats like the cells having mutated DNA, which can grow and multiply to become carcinogenic, or even the body cells infected with the viruses.

Blood platelets and some of the proteins that are dissolved in plasma interact to produce clots blocking the ruptured sites of blood vessels when the vessels get damaged, leading to bleeding. Hence, the body is prevented from any further loss of blood.

Transportation – Role of Blood in Transportation

The food we consume has nutrients that are absorbed in the digestive tract. Most of the nutrients directly pass from the bloodstream to the liver, which is processed and released into the bloodstream to deliver to the cells of the body.

Oxygen diffuses into the blood that moves from the lungs to the heart, which then is pumped to the entire body. Additionally, the blood picks the by-products and cellular wastes too, and passes them to different structures to be eliminated.

Homeostasis – Role of Blood in Maintaining Homeostasis

The body temperature is regulated through the negative-feedback loop. When blood passes through the vessels of the skin, heat can be dissipated to the environment and the blood getting back to the body can be cooler. On the contrary, on a colder day, blood gets diverted from the skin to preserve a warmer tone. If conditions are extreme, it can lead to frostbite.

Also, blood aids in maintaining the balance of chemicals in the body. The pH of tissues is regulated by the buffers found in the blood, such as proteins and associated compounds. Further, blood also aids in regulating the water content of the cells.

Some other functions of blood

Apart from the above-mentioned functions, blood is involved in performing the following roles too –

- Blood aids in eliminating urea, lactic acid and carbon dioxide
- Involved in immunological functions, such as circulation of the white blood cells, identifying foreign particles by the antibodies

- It responds to broken blood vessels, coagulation, converting blood from liquid to a semisolid gel that stops bleeding
- Involved in hydraulic functions
- Performs messenger functions, even that of transporting hormones and signalling tissue damage

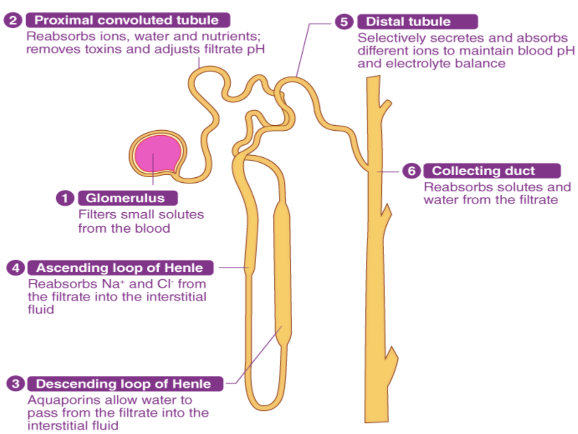
Excretion is a biological process, which plays a vital role in eliminating toxins and other waste products from the body. In plants and animals, including humans, as part of metabolism, a lot of waste products are produced. Plants usually excrete through the process of transpiration and animals excrete the wastes in different forms such as urine, sweat, faeces and tears. Among all these, the usual and the main form of excretion is urine.

Urine Formation

Waste is excreted from the human body, mainly in the form of urine. Our kidneys play a major role in the process of excretion. Constituents of normal human urine include 95 per cent water and 5 per cent solid wastes. It is produced in the nephron, which is the structural and functional unit of the kidney. Urine formation in our body is mainly carried out in three phases namely

1. Glomerular filtration
2. Reabsorption
3. Secretion

Mechanism of Urine Formation



The mechanism of urine formation involves the following steps:

Glomerular Filteration

Glomerular filtration occurs in the glomerulus where blood is filtered. This process occurs across the three layers- the epithelium of Bowman's capsule, the endothelium of glomerular blood vessels, and a membrane between these two layers.

Blood is filtered in such a way that all the constituents of the plasma reach the Bowman's capsule, except proteins. Therefore, this process is known as ultrafiltration.

Reabsorption

Around 99 per cent of the filtrate obtained is reabsorbed by the renal tubules. This is known as reabsorption. This is achieved by active and passive transport.

Secretion

The next step in urine formation is tubular secretion. Here, tubular cells secrete substances like hydrogen ions, potassium ions, etc into the filtrate. Through this process, the ionic, acid-base and the balance of other body fluids are maintained. The secreted ions combine with the filtrate and form urine. The urine passes out of the nephron tubule into a collecting duct.

Urine

The urine produced is 95% water and 5% nitrogenous wastes. Wastes such as urea, ammonia, and creatinine are excreted in the urine. Apart from these, the potassium, sodium and calcium ions are also excreted.

Osmoregulation

Osmoregulation is the process of regulating body fluids and their compositions. It maintains the osmotic pressure of the blood and helps in homeostasis. This is why it is recommended to consume more water about 2-3 litres, which helps in the proper functioning of our kidneys. For example, we consume lots of water during summers, but still, we urinate fewer times in summers than in winters and the concentration of the urine is also more. The reason is that we lose lots of water from our body in summer through sweating. Thus, to maintain the fluid balance in the body our kidneys reabsorb more water.

Key Points on Urine Formation and Osmoregulation

- Urine is formed in three main steps- glomerular filtration, reabsorption and secretion.
- It comprises 95 % water and 5% wastes such as ions of sodium, potassium and calcium, and nitrogenous wastes such as creatinine, urea and ammonia.
- Osmoregulation is the process of maintaining homeostasis of the body.
- It facilitates the diffusion of solutes and water across the semi-permeable membrane thereby maintaining osmotic balance.
- The kidney regulates the osmotic pressure of blood through filtration and purification by a process known as osmoregulation.

URINE PROFILE

A urine profile (urine ACR, urea, albumin, sugar) assesses kidney function and screens for damage, often caused by diabetes or high blood pressure. Normal albumin is < 30 mg/g (< 3 mg/mmol), with higher levels indicating albuminuria. Key findings: 30 – 300 mg/g indicates moderate damage (microalbuminuria), > 300 mg/g shows severe damage (macroalbuminuria), and high urine glucose/sugar indicates diabetes. MedlinePlus (.gov) +4

Key Components of Urine Profile

- **Urine Albumin-to-Creatinine Ratio (uACR):** This is the most critical part, comparing albumin (a protein) to creatinine (a waste product) in the urine. It helps detect small amounts of protein that indicate early kidney damage.
- **Albumin (Microalbumin):** A type of protein in the blood. Healthy kidneys prevent it from entering the urine. High levels (albuminuria) indicate kidney disease.
- **Creatinine:** A waste product from muscle metabolism, used to normalize albumin levels in the urine to ensure accuracy regardless of how concentrated the urine is.
- **Urine Sugar (Glucose):** Used to detect high blood sugar levels. A normal finding is zero or very low sugar. Elevated levels are often a sign of diabetes.
- **Urine Urea:** While less common in a standard Urine ACR, measuring urea nitrogen in urine helps evaluate protein metabolism and kidney function, often compared with blood tests.

Typical Reference Ranges & Interpretation

- **Normal:** Less than 30 mg/g (< 3 mg/mmol).
- **Moderate Increase (Microalbuminuria):** 30 – 300 mg/g (3 – 30 mg/mmol).
- **Severe Increase (Macroalbuminuria):** Over 300 mg/g (> 30 mg/mmol).
- **Urine Sugar:** Generally, glucose should not be present in urine. MedlinePlus (.gov) +4

Indications for Testing

- Diabetes (Type 1 or 2)
- High blood pressure (Hypertension)
- Family history of kidney disease
- Signs of kidney damage (e.g., foamy urine, swelling in hands/feet)

Two high results over 3 or more months indicate chronic kidney disease (CKD)

Normal urine color ranges from pale yellow to deep amber, reflecting hydration levels, with a normal specific gravity (USG).

Darker urine usually indicates higher concentration (high USG, >, dehydration), while lighter or colorless urine suggests lower concentration (low USG, high fluid intake).

Key Urine Color and Specific Gravity Correlations

- **Clear to Light Yellow:** Low Specific Gravity. Suggests well-hydrated, high water intake, or potentially dilute urine from conditions like diabetes insipidus.
- **Transparent/Pale Yellow:** Normal Hydration.
- **Deep Yellow/Amber:** High Specific Gravity
- **Orange:** Very high specific gravity, may indicate dehydration or medication/dietary factors.

Factors Affecting Results

- **Specific Gravity (USG):** Measures urine concentration of dissolved solids. High levels (>1.030) can indicate dehydration, kidney issues, or excessive substances (like glucose). Low levels (<1.005) can indicate overhydration or renal issues.
- **Color Changes:**
    - **Red/Pink:** Blood (hematuria), foods (beets), or medication.
    - **Blue/Green:** Pseudomonas infection, meds, or rarely Biliverdin.
    - **Cloudy:** UTIs, crystals, or white blood cells.