8 The Circulatory System

In the Chapter

Syllabus : *Circulatory System : Blood and lymph, the structure and working of the heart, blood vessels, circulation of blood (only names of the main blood vessels entering and leaving the heart, liver and kidney will be required). Lymphatic system.*

Scope of Syllabus :

- Composition of blood (structure and functions of RBC, WBC and platelets).
- Brief idea of tissue fluid and lymph.
- Increase in efficiency of mammalian red blood cells due to absence of certain organelles; reasons for the same.
- A brief idea of blood coagulation.
- Structure and working of the heart along with names of the main blood vessels entering and leaving the heart, the liver and the kidney.
- Concepts of systole and diastole; concept of double circulation.
- Brief idea of pulse and blood pressure.
- Blood vessels : artery, vein and capillary to be explained with the help of diagrams to bring out the relationship between their structure and function.
- Brief idea of the lymphatic organs : spleen and tonsils.
- ABO blood group system, Rh factor.
- Significance of the hepatic portal system.

Almost all organisms, including humans, have some kinds of fluids circulating in their bodies. Such fluids constitute the distributing system (to supply substances) as well as a collecting system (to pick up substances) to and from the various parts of the body including the remotest cell. In this chapter, we will study about the circulating fluids in our body, their composition and function.

8.1 NEED FOR TRANSPORT INSIDE THE BODY

Every organ in our body requires the involvement of the circulating body fluids. *For example* :

- The **digestive system** digests and absorbs nutrients which are needed to be transported to every cell of the body.
- **The respiratory system** draws in air, and the oxygen picked up from it in the lungs has to be transported to all parts of the body. Similarly, the CO_2 collected from the entire body has to be carried to the lungs to be exhaled out of the body.
- All the extra water, excess salts, and the nitrogenous wastes such as urea have to be removed from different parts and have to be sent to the **excretory system** to be thrown out of the body.
- **Hormones** secreted by the endocrine system have to be carried throughout the body by the circulating blood to act wherever required, and so on.

Read all points & write in your own words in short

All such functions that need transport are performed by the two ***circulating fluids*** – the **blood** and the **lymph**. Besides transport, these fluids have some other functions also.

8.2 FLUIDS IN OUR BODY

There are three principal fluids in our body :

(i) **Blood**, contained in the heart and in the blood vessels (arteries, veins and capillaries) of the circulatory system.

(ii) **Tissue fluid**, occupying spaces between cells in the organs.

(iii) **Lymph**, which is contained within lymph vessels and lymphatic organs such as the spleen and the tonsils.

The above three principal fluids in our body are respectively described in section 8.3 (*blood*) and section 8.9.3 (*tissue fluid* and *lymph*).

Fig. 8.1 shows a diagrammatic representation of the relationship between blood, tissue fluid and lymph as they *circulate in their respective vessels* or spaces between the cells in different organs. It is clear from the diagram that blood in our body circulates in a closed manner *i.e.* all the time through blood vessels. Such a type of blood circulation is called a **closed blood circulatory system**. As against this, in certain animals such as insects, the blood mostly flows through open spaces in the body, called an **open blood circulatory system**. Their blood flows from the heart to body spaces without vessels.

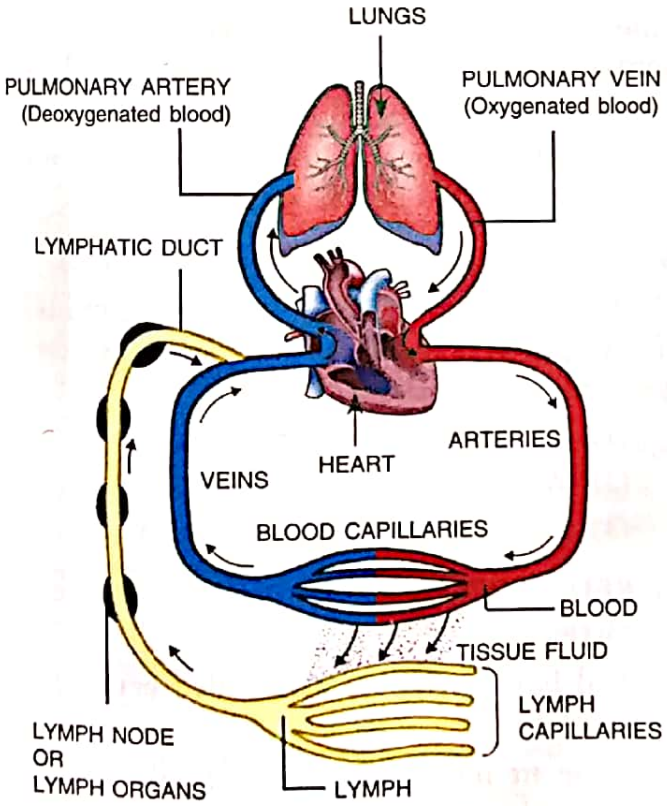


Fig. 8.1 Diagrammatic representation of blood and lymph circulation (Red-oxygenated blood, Blue-deoxygenated blood).

The colour differentiation

Arteries — Red **Veins — Blue**

Conventionally in the diagrams, we show arteries in red colour and veins in blue. This colour differentiation is not wholly true. The oxygenated blood transported by the arteries is *bright red*, but the deoxygenated and CO_2 transporting blood is dark red (certainly not blue). But if you ever look at the prominent veins on the arms or hands especially of the old people outwardly they do look bluish and that is due to the less thicker muscular walls of the veins.

Non-circulating fluids : There are also some other fluids located in particular organs such as **synovial fluid** filled in the cavities of skeletal joints, **vitreous humour** in the eye, etc. They do not circulate.

8.3 PROPERTIES OF BLOOD : THE BLOOD

- **Never Stationary** — Blood is always in motion from the heart to the arteries and back through the veins.
- **Colour** — The blood is a somewhat thick fluid, **bright red** when taken from an artery or **dark red** when taken from a vein.
- **Volume** — An average adult human has 5 to 6 litres of blood by volume in his body.
- **Taste - saltish** — Perhaps we have all "tasted" our blood as in the case when there is a cut in the tongue or bleeding from the gums. It tastes saltish. The blood is slightly alkaline with a pH of 7.3 to 7.45 (7 is neutral, neither acidic nor alkaline).

8.5 FUNCTIONS OF BLOOD

The main functions of the blood in our body can be treated under two broad headings: (A) Transport and (B) Protection.

A. TRANSPORT BY BLOOD (Transport of digested food, oxygen, carbon dioxide, excretory substances, hormones, body heat).

1. **Transport of digested food** from the alimentary canal to the tissues. These substances are simple sugars like glucose, amino acids, vitamins, mineral salts, etc.
2. **Transport of oxygen** from the lungs to the tissues. It occurs by means of red blood cells in combination with haemoglobin in the form of an unstable compound oxyhaemoglobin, which on reaching the tissues breaks up to deliver oxygen.

$$Hb + O_2 \rightleftharpoons \underset{\text{oxyhaemoglobin}}{Hb.O_2}$$

3. **Transport of carbon dioxide** from the tissues to the lungs. It occurs partly in combination with haemoglobin and partly as solution in blood plasma.

$$Hb + CO_2 \rightleftharpoons \underset{\text{carbaminohaemoglobin}}{Hb{\cdot}CO_2}$$

4. **Transport of excretory material** from the tissues to the liver, kidney or the skin for elimination or to render them harmless.
5. **Distribution of hormones** secreted by special glands (endocrine glands) directly into the blood.
6. **Distribution of heat.** The blood helps in keeping the temperature of the body uniform by distributing heat.

B. PROTECTION BY BLOOD

1. Blood forms a **clot** wherever there is a cut in a blood vessel. The clot serves to **prevent**
   (i) further loss of blood and
   (ii) the entry of disease-causing germs.
2. Its white blood corpuscles *protect the body from* diseases by **engulfing bacteria** which may have entered the body.
3. It produces **antitoxins** and **antibodies** which neutralise the poisonous substances or kill the germs which enter the body.

? Progress Check

1. Name the two fluids that circulate in the body.
2. In a coloured diagram, why do we generally show the pulmonary artery in blue and pulmonary vein in red colour ?
3. Name any four substances transported by blood.

8.5 COMPOSITION OF BLOOD

The blood consists of :

(i) **Plasma** – fluid part, constitutes 55-60 per cent of blood.

(ii) **Cellular elements** – red and white cells, and platelets, 40-45 per cent of blood.

8.5.1 PLASMA — The liquid portion of blood

The plasma is a light-yellow coloured, alkaline liquid. It mainly consists of :

Water	–	90 - 92%
Proteins	–	7 - 8%
Inorganic salts	–	1%
Other substances	–	traces

The inorganic salts mainly include **sodium chloride** and **sodium bicarbonate**. Among other substances contained in the plasma are **glucose, amino acids, fibrinogen, hormones, urea**, etc.

The plasma from which the protein fibrinogen has been removed is called **serum**.

8.5.2 CELLULAR ELEMENTS (Fig. 8.2)

The formed or cellular elements of the blood (*i.e.* shaped structures visible under magnification) are of three categories :

(1) Red blood cells (**erythrocytes**)
(2) White blood cells (**leukocytes**)
(3) Blood platelets (**thrombocytes**)

(1) RED BLOOD CELLS (RBCs) — The oxygen carriers

Red blood cells are also called **erythrocytes** (*erythros*: red)

- These are minute biconcave disc-like structures, flat in the centre and thick and rounded at the periphery.

DEFICIENT, BUT MORE EFFICIENT !

Mammalian Red Blood Cells

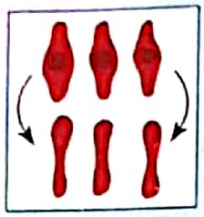
Mammalian red blood cells when mature circulate in the blood system and are devoid of certain organelles. They have

— no **nucleus**

— no **mitochondria**

— no **endoplasmic reticulum**

Thus, though deficient of the above organelles, the mature red blood cells, in reality, are more efficient in carrying out their task of picking up and delivering oxygen. The factors making them more efficient in this work are as follows :



1. **Loss of nucleus**, makes the red cells biconcave, thus increasing their surface area volume ratio for absorbing more oxygen.
   — Space in between increased
   — More RBCs can be accommodated in the same space
2. **Loss of mitochondria** means that the red cells cannot use oxygen for themselves (cellular respiration occurs in mitochondria). Thus all the oxygen, absorbed from the lungs, is transported and delivered to the tissues unconsumed. Secondly, loss of mitochondria means full transport of glucose in blood plasma, unused by the RBCs.
3. **No endoplasmic reticulum** means increased flexibility of RBCs for their movement through narrow capillaries.

More about the number of RBCs

- New born infants have a larger number of RBCs — about 6-7 million per cubic millimetre (1 mm^3).
- RBC count is lowered by 5% during sleep.
- RBC count is higher during physical activity, pregnancy and emotional upsets.
- People living at a height of 4,200 m and above, increase their RBCs by nearly 30%.
- Abnormally increased number of RBCs is called ***Polycythaemia***, and their abnormally decreased number is known as ***Erythropenia***.

(2) WHITE BLOOD CELLS (WBCs) — White blood cells, or **leukocytes** (*leuko* : white), differ from red blood cells in having a nucleus and not containing haemoglobin. Their number is much less, usually about **4000-8000 per mm^3** of blood.

Most WBCs are amoeboid and can produce pseudopodia with which they can squeeze through the walls of the capillaries into the tissues (**diapedesis** *dia* : across, *pedesis* : oozing out) (Fig. 8.3).

Based on shape and other characteristics, the white blood cells are classified into two major categories (granular and non-granular) and five distinct types (Table 8.1 given on next page and Fig. 8.2) as follows :

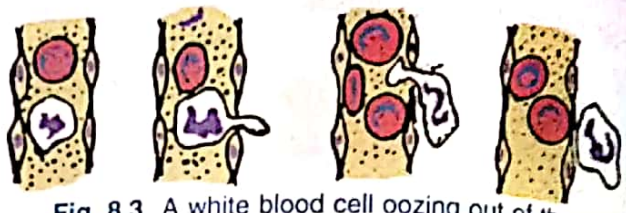


Fig. 8.3 A white blood cell oozing out of the blood vessel (diapedesis).

White Blood Cell Or White Cells ?

The better term is "white cells" or leukocytes (**leukos** : white) because they spend most of their time (90%) in tissue fluid or in the lymph and very little time (only about 10%) in the blood.

Origin and life of WBCs :

The WBCs are produced in red bone marrow, lymph nodes and sometimes even in liver and the spleen. Their average life is about two weeks. The neutrophils live for only a few hours, and about 125 billion neutrophils are produced each day. The old and worn out WBCs are destroyed in the same manner as the RBCs.

Read

Leukemia *is a cancer of the tissue forming WBCs whose number increases manifold at the cost of RBCs. It is usually a fatal disease. Currently, the treatment is only blood transfusion.*

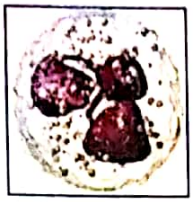
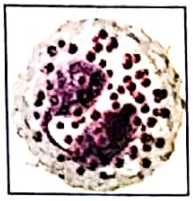
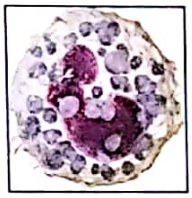
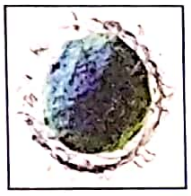
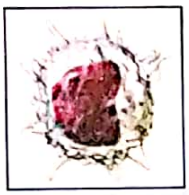
Leukopenia *is the abnormal decrease in the number of WBCs.*

Functions Of Leukocytes (WBCs) — Body defence

1. *Phagocytosis* : This is a process in which most WBCs and particularly the **neutrophils engulf particle-like solid substances, especially bacteria**. This is a defensive mechanism against disease germs. An abnormal increase

learn from here only.

Table 8.1 Different types of white blood cells (Leukocytes) after staining.

Two major categories of WBCs	Five cell types (abundance)	Appearance	Distinguishing features	Functions	Site of production
A. **Granular** • Cytoplasm contains granules • Nucleus usually constricted into lobes	1. Neutrophils (62%)		• Nucleus with 3-4 lobes • Granular cytoplasm • Stain with neutral dyes	Engulf bacteria (Phagocytosis)	Bone marrow
	2. Eosinophils (2·3%) [count increases in allergies]		• Nucleus with 2 lobes • Large cytoplasmic granules • Stain dark red with eosin (acid dye)	• Engulf bacteria • Secrete antitoxins • Associated with allergy	Bone marrow
	3. Basophils (0·4%)		• Nucleus large and indistinctly lobed • Granules stain with basic dyes (e.g. methylene blue)	Release chemicals (histamine) for **inflammation** which dilate blood vessels	Bone marrow
B. **Non-granular** • Cytoplasm without granules • a single large nucleus	4. Lymphocytes (30%)		• **Smallest** of WBCs • Single large nucleus	Produce **antibodies**	Bone marrow and Lymph glands (spleen, tonsils, etc.)
	5. Monocytes (5·3%)		• **Largest** of WBCs • Nucleus large, kidney-shaped • At the site of infection, transform into macrophages	Ingest germs	Bone marrow

in WBC count up to about 50,000 or more per cubic mm indicates some infection in the body.

2. ***Inflammation*** : Inflammation occurs due to the reaction of tissues to injury and to localized invasion of germs. The inflamed spot has several characteristics: increased **local heat, redness, swelling, pain,** *etc.* Here the leucocytes (specially the monocytes and neutrophils) migrate through the walls of the blood vessels by **diapedesis** (Fig. 8.3), and fight against disease-causing germs. They also **destroy the damaged cells** by phagocytosis.

Pus is mainly composed of the dead white blood cells together with the tissue cells destroyed by the bacteria.

Formation of antibodies : The WBCs (specially the **lymphocytes**) produce antibodies which kill or neutralise the germs, or the poisons from them. Introducing weakened germs or germ substances (vaccines) during vaccination stimulates formation of particular antibodies which, at a later period, would destroy the particular disease-causing germs if they enter into the body.