BIOLOGY

CIRCULATORY SYSTEM

CLASS -10

SYLLABUS

Human Anatomy and Physiology

- *Circulatory System : Main features; the structure and working of the heart, blood vessels, structure and functions of blood and circulation of blood (only names of the main blood vessels entering and leaving the heart, liver and kidney will be required).*
- *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 should be explained with reasons. A brief idea of blood coagulation. Structure of vein, artery and capillary should be explained with the help of diagrams to bring out clearly the relationship between their structure and fucntion. ABO blood group system, Rh factor; concept of double circulation; concept systole and diastole; blood pressure. Reference to portal system should be made. Working of the heart along with names of the main blood vessels entering and leaving the heart, the liver and the kidney must be taught. Examination of a blood smear under a microscope.*

CIRCULATORY SYSTEM

In a multicellular body each and every cell is not in the direct contact of external environment to get its required food, oxygen and other vital components. At the same time the various metabolic wastes produced in the body which may prove poisonous are also required to be removed.

Therefore, a transport system is required to provide the body cells with vital components and also to help in the distribution of useful products in the body. It also helps in the elimination of wastes. This transport system of the body is called the circulatory system. The functions of the circulatory system can be summarised as below :

1. It supplies oxygen to different cells of the body.
2. It helps in the removal of CO_2.
3. It helps in the distribution of nutrient to all the cells of the body.
4. It helps in homeostasis (maintains a constant internal environment in terms of temperature, pH etc.).
5. It helps in the elimination of excretory wastes.
6. It helps in the defence of the body.

TYPES OF BODY FLUIDS

The total body fluid is distributed between two main compartments within our body. These are:

1. Extra-cellular Fluid (ECF) : The body fluids that are not inside the cells are collectively known as extracellular fluids. These fluids make up about one fourth of a person's body weight. It has high concentration of Na^+ ions. ECF is represented by the following types of fluids, *viz.*,

(a) Interstitial Fluid or the Tissue fluid : It directly surrounds the tissues and fills the spaces between them.

(b) Blood Plasma : It flows in the arteries and veins.

(c) Lymph : It flows through the lymph vessels.

(d) Non-circulating fluids like synovial fluid at the joints and the vitreous humour in the eye.

2. Intracellular Fluid (ICF) : It represents the cytoplasmic fluid contained within the body cells. It represents larger compartment with approximately two thirds of the body weight. It has high concentration of K^+ ions.

BLOOD VASCULAR SYSTEM

Blood vascular system is a system of vessels through which the blood flows. The direction of blood flow is regulated by a pumping orga n the heart.

The circulatory system can be of two types :

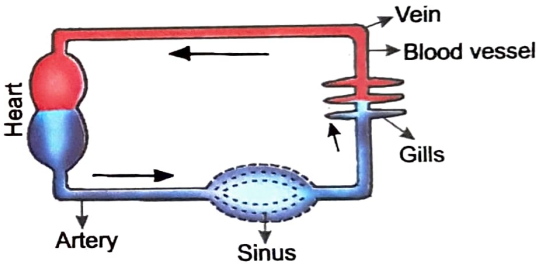
(a) Open circulatory system

(b) Closed circulatory system

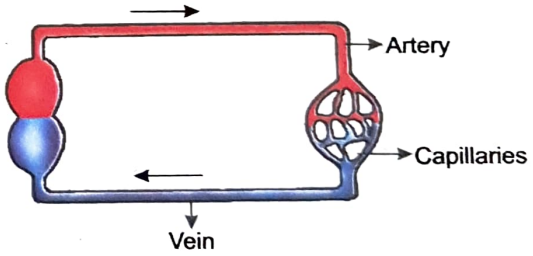
(a) Open Circulatory System : In open circulatory system capillaries are absent and arteries open into large spaces (cavities) called blood sinuses from where blood enters into veins, *e.g.*, Arthropoda, mollusca etc.

(b) Closed Circulatory System : In closed circulatory system blood capillaries are present between arteries and veins and blood sinuses are absent. This is more efficient than open circulatory system, *e.g.*, Annelida and all vertebrates.

Blood vascular system consists of blood, heart and blood vessels (arteries, veins and capillaries).



Open circulatory system



Closed circulatory system

Fig. 1. Major types of circulatory system.

BLOOD

Blood is a fluid connective tissue. Normal blood volume for adult ranges 4.5-5.5 litres for a woman and from 5 to 6 litres for a man. The blood is slightly alkaline with a pH of 7.4. The specific gravity of blood is 1.05 to 1.06. When oxygenated it is bright red as in arteries but when deoxygenated it is dull red as in vein.

Blood consists of a liquid part called plasma and many cells called blood corpuscles or formed elements floating in the plasma.

PLASMA

Plasma is the whole blood minus the formed elements (blood cells and platelets) floating in it. Serum on the other hand is the plasma from which fibrinogen is removed during clotting.

Components of Blood:

Blood

Plasma

- Fluid parts of the blood
- Contains water, inorganic salts, proteins, etc.
- Helps to transport gases and digested food materials, regulates body heat, maintains pH of blood, etc.

Corpuscles Cells (called cellular or formed elements)

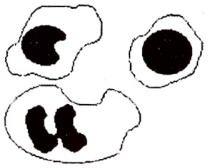
Erythrocytes/RBCs

- Biconcave shaped
- Mature RBC does not contain nucleus, mitochondria and ER
- Lifespan is 120 days.
- Contains red-coloured pigment, haemoglobin, which helps to transport respiratory gases.

Red blood cells

Leucocytes/WBCs

- Irregular shaped
- Helps to fight with germs.



White blood cells

Thrombocytes/Platelets

- Round or oval-shaped
- Helps in the clotting of blood.

Platelets (greatly magnified)

. The summary of the blood corpuscles is given below:

	Cells	Structure	Function
I.	RBCs	Biconcave, or enucleate disc-shaped	To transport respiratory gases
II.	WBCs	Irregular and nucleated	Defend against microbes
	(*i*) Granulocytes	Granular cytoplasm and multilobed nucleus	
	(*a*) Neutrophil	3-4 lobed nucleus	Phagocytosis (engulfing microbes)
	(*b*) Eosinophil	Bilobed nucleus	Phagocytosis (engulfing microbes) secretes antitoxin; associated with allergy
	(*c*) Basophil	Nucleus large, 3 or many lobed, and irregular	Produce histamine, heparin, etc.
	(*ii*) Agranulocytes	Cytoplasm without granules	Helps in wound healing
	(*a*) Lymphocyte	Nucleus round or slightly indented	Produce antibody
	(*b*) Monocyte	Kidney-shaped nucleus	Phagocytosis
III.	Platelets	Round or oval-shaped	Clotting of blood

Features of Plasma :

(a) It is about 55% of the total blood volume.

(b) It is a transparent, alkaline fluid of straw colour (due to bilirubin).

(c) It is composed of about 92% water and about 8% solids.

(d) The solid part of the plasma consists of :

- **Proteins :** Represent about 8% of the total solid parts. These include :
  1. **Albumin :** Maintain osmotic pressure of the blood.
  2. **Globulin :** Help in transportation of substances, γ globulin or immunoglobulin form antibodies and help in defence.
  3. **Fibrinogen** and **prothrombin** help in clotting of blood.

  Proteins also help in maintaining the pH of the blood.
- Other **organic substances** present in the blood are glucose and traces of other sugars, amino acids, cholesterol, hormones and urea, enzymes etc.
- **Inorganic substances** include chloride and bicarbonates mainly of Na^+, K^+ and Ca^{++} etc., which maintain pH of the blood.

BLOOD CORPUSCLES

The formed element or the cellular part of the blood consists of :

(a) Red blood cells (Erythrocytes)

(b) White blood cells (Leucocytes)

(c) Platelets (Thrombocytes)

Red Blood Cells (Erythrocytes) : They are small circular, biconcave, disc like measuring about 8 μm in diameter and 2 μm in thickness. Their biconcave area provides more surface area favouring more diffusion of O_2 and CO_2. Being elastic and flexible they can easily pass through the tiny capillaries.

In normal adult the RBC count is about 5 million per cubic mm for male and about 4.5 million per cubic mm for female. RBC count may increase under the condition of hypoxia on increased demand of oxygen by the body. The increased amount of RBC in the body is called polycythemia and is responsible for the rosy cheeks of the people on the hills. The decreased RBC count is called anaemia. Mature RBC is enucleated in mammals including man which allows it to be biconcave. RBC also, lack other cell organelle as well including mitochondria. These conditions allows more surface for the accommodation of more haemoglobin. Lack of mitochondria prevents use of O_2 by RBC itself.

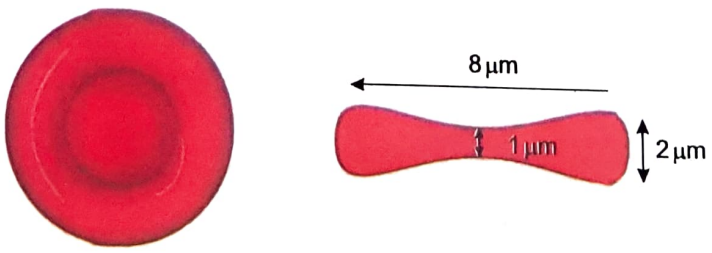


Fig. 2

Individual RBC is pale yellow in colour due to presence of haemoglobin. Haemoglobin is a respiratory pigment containing an iron containing part called haem, which is conjugated with the globin protein. One molecule of haemoglobin can transport four molecules of oxygen. Haemoglobin

combines reversibly with oxygen in the lungs to form oxyhaemoglobin. On reaching the tissues, it dissociates to release oxygen which can be used by the tissues.

$$Hb + O_2 \rightleftharpoons HbO_2$$

Haemoglobin has some affinity for CO_2 but has comparative high affinity for CO forming carboxyhaemoglobin which causes death of the organism. It combines with CO_2 to form carbaminohaemoglobin.

Normal adult blood contains approximately 15 gm of haemoglobin per 100 ml of blood.

The formation of red blood cells is called erythropoiesis. In embryo red blood corpuscles are formed in liver and spleen but in adults the formation of RBCs is confined to the red bone marrow of long bones (like humerus, femur, ribs), sternum, vertebrae and pelvis. The life span of RBC is about 120 days. The old, weak and injured RBCs are destroyed in spleen thus spleen is referred to as graveyard of RBCs. Destruction of RBCs produces bilirubin and biliverdin which are called bile pigments. Breakdown of RBC is called haemolysis.

Function : RBCs are concerned with the transportation of O_2 and CO_2.

LEUCOCYTE

Leucocytes are called white blood cells because they lack any pigment and are colourless. They are nucleated and mostly amoeboid. They are capable of squeezing through the wall of blood capillaries with the help of their pseudopodia. The process is called diapedesis. The blood a normal adult contains 6,000 to 8,000 WBCs per cubic mm. The increase in the number of WBCs is called leucocytosis but if increase is at the cost of RBCs it is called leukaemia. The decrease in the number of WBCs is called leucopenia. These are produced in bone marrow and lymph nodes. Their life span is about two weeks.

WBCs are of two types : granulocytes and agranulocytes.

GRANULOCYTES

The leucocytes with granules in their cytoplasm are called granulocytes. They contain a complex lobulated nucleus and are therefore called polymorphonuclear leucocytes (PMNLs) or polymorphs. These are of three types :

(a) Neutrophils : They are stained with neutral dyes or with a mixture of acidic and basic dyes. Their cytoplasm has fine granules and a multilobed (2-5) nucleus. They are 50 to 70% of TLC (Total Leucocyte Count).

These corpuscles are actively motile and phagocytic.

(b) Eosinophils : They are stained with acidic dye eosin. Therefore these are also called acidophils. Their nucleus is bilobed and cytoplasm has coarse granules. They play important role in immunity, allergy and hypersensitivity. They are 1-5% of TLC.

(c) Basophils : They are stained with basic dye methylene blue. Their nucleus is multilobed with 'S' shaped structure. They are concerned with the secretion of heparin (an anticoagulant) and histamine, a vasodialator that also increases capillary permeability for inflammatory reaction. They are 0-1% of TLC.

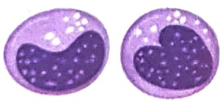
AGRANULOCYTES

These leucocytes lack granules in their cytoplasm. Their nucleus is without lobes. These are of following two types :

(a) Lymphocytes : Lymphocytes are smallest white blood cells. They have round and eccentrically placed nucleus.

Lymphocytes produce antibodies. They are 25 to 30% of TLC.

Table 1. Types of WBCs.

Type	Diagram	Shape of the nucleus	Approx. DLC	Function
Neutrophils		Multilobed	62%	Destroy Bacteria and Fungi by phagocytosis
Eosinophils		Bi-lobed	2.3%	Destroy larger parasites like helminthes. Responsible for symptoms of allergy and inflammation
Basophils		Bi-lobed or tri-lobed	0.4%	Release heparin (anticoagulant) and histamine (during inflammation)
Lymphocytes		Large and eccentrically placed	30%	**B cells:** release antibodies **T cells:** regulate the overall functioning of the immune system
Monocytes		Kidney shaped	5.3%	Remove dead cell debris and attack microorganisms

(b) Monocytes : Monocytes are the largest leucocytes. They are produced in liver, thymus, bone marrow, spleen and lymph nodes and are destroyed in liver and spleen, after 2 weeks of production. They have kidney shaped nucleus. They constitute about 5% of the TLC. Monocytes are concerned with phagocytosis of dead cells.

PLATELETS (THROMBOCYTES)

Platelets are formed by the fragmentation of megakaryocytes in bone marrow. Platelets are enucleated and are the smallest blood cells. Normally their number ranges from 1,40,000 to 3,40,000 per mm^3.

Platelets form factors which initiate coagulation of blood. Besides, due to their adhesive properties they clump together at the damage site of blood vessels plugging the injured part.

COAGULATION OF BLOOD

Blood attempts to minimise or prevents its loss when a blood vessel is open and damaged (haemostasis). It is efficient in doing so due to its inherent property of coagulation or clotting. The coagulation is a process of formation of blood clot (a patch of semisolid meshed blood similar to

Blood Coagulation or Clotting: When a blood vessel is injured, a clot is formed in order to prevent excessive bleeding. This process of clot formation is called blood clotting or coagulation.

Mechanism of Clotting of Blood: It takes place in a series of steps:

(*a*) Platelets migrate to the injured tissue. The platelets release an enzyme thromboplastin/ thrombokinase.

(*b*) In the presence of calcium ions, thromboplastin converts inactive prothrombin into active thrombin.

(*c*) Thrombin in the presence of Ca^{++} ions reacts with soluble fibrinogen and converts it into insoluble fibrin, and a mesh is formed.

(*d*) The mesh of fibrin traps blood cells and releases plasma (serum). The left over solid mass is clot (thrombus).

gelatin in consistency) which plugs the damaged part of a blood vessel to check the further loss of the blood.

Stage I : Conversion of prothrombin into thrombin. When a blood vessel is cut due to injury, tissues and platelets are also injured at site of damage. These release an enzyme, called thromboplastin. This enzyme converts prothrombin (an inactive enzyme), already present in the plasma, into thrombin (active form of prothrombin) with the help of calcium ions.

Stage II : Conversion of fibrinogen into fibrin. Fibrinogen is a soluble protein present in circulating plasma. Thrombin changes it to insoluble fibrin.

Stage III : Formation of clot. Fibrin threads form a network. In this net, blood cells are trapped, leading to formation of blood clot.

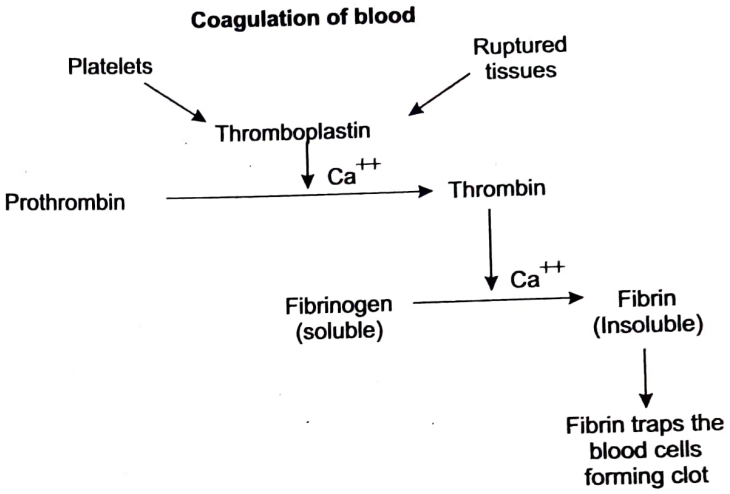


Fig. 3. Graphic outline of events during coagulation of blood.

Over a period of few hours, the blood clot retracts, releasing yellowish fluid, the serum which checks infection at site of the clot formation. Usually, blood does not clot within a blood vessel because thromboplastin is not available in it. Moreover, the plasma has heparin (an anticoagulant), which does not allow spontaneous conversion of prothrombin into thrombin, Vitamin 'K' is necessary for clotting as it helps in the formation of prothrombin.

FUNCTIONS OF BLOOD

1. Blood transports the nutrients absorbed from intestine to all parts of the body.
2. It transports oxygen from lungs to tissues and carries carbon dioxide from tissues to lungs.
3. It collects metabolic wastes from cells and transports them to excretory organs to be removed outside the body.
4. It distributes hormones to different parts of the body.
5. It protects body from germs, foreign materials and poisons by producing antibodies or by phagocytosis with the help of WBCs.
6. It coagulates at the site of the injury and checks blood loss.
7. It regulates body temperature by distributing heat in the body (thermoregulation).
8. It maintains constant environment in the body by regulating water and salt concentration of body fluid (homeostasis)

BLOOD GROUPS AND TRANSFUSION

Sometimes, there is a heavy blood loss during operation or a severe injury. When there is more than 40% loss of blood volume, the body is not able to regain the lost volume of the blood without an aid from the outside and under such condition, there is a risk to life of the affected person.

Usually, the blood for transfusion is obtained from a healthy person. The person who donate his blood for transfusion into body of another person is called donor and the person who receives the blood is called recipient. The donor's blood is termed incompatible if it does not match with that of the recipient. The donor's blood must be compatible (matching) to the recipient's blood.

Karl Landsteiner and others have discovered that entire human population is divided into four major groups on the basis of reaction of bloods of person when mixed together. These groups are called blood groups and, designated as A, B, AB and O blood groups. This grouping is based on presence or absence of one or both antigen A and antigen B. In normal blood, if an antigen is present in the RBC, its corresponding antibody is absent in plasma. For example, if antigen A is present in the RBC, the plasma lacks antibody a. Likewise, if antigen B is present, the antibody b is absent. Antigen A and B may be present in the same person with absence of antibody.

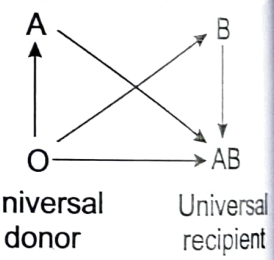
Likewise, antibodies a and b may be present together in the plasma without presence of any antigen in red blood cells.

Table **2.** Distribution of antigens and antibodies in ABO system of blood groupings.

Blood group	Antigen (Agglutinogen) on RBC membrane	Antibody (Agglutinin) in plasma
A	A	b
B	B	a
AB	A and B	Neither a nor b
O	Neither A nor B	a and b

The blood group O can donate blood to all blood groups (A, B, AB and O) and hence this is called universal donor. Person with blood type AB can receive blood from all blood groups (A, B, AB and O) and therefore is called universal recipeint but it can donate blood to only blood group AB.

The blood group A can receive blood from blood group A and O but it can donate blood to blood groups A and AB. The blood group B can receive blood from blood groups O and B but it can donate blood only to blood group AB. However, the blood group O can receive blood only from the blood group O.



Rh FACTOR

Rh factor, first discovered in 1940, is named after rhesus monkey (common monkey) in which it was discovered. This factor is actually a group of antigens present in plasma membrane of the red blood cells. Persons having Rh factor are called Rh positive (Rh^+) but a person who lacks this factor is called Rh negative (Rh^-). If blood group of the father is Rh^+ and that of the mother is Rh^-, it can create complications in the pregnancy, sometimes resulting in the death of the fetus.

UNIVERSAL DONOR AND UNIVERSAL RECIPIENT

Universal donor are the humans with O^- blood group. In O^- blood group the RBCs have no antigen but both the antibodies. At the time of blood transfusion donor's antigen and recepients antibodies are considered for compatability. Since O^- has no antigen, it will not induce antibody production in the recipient and thus agglutination due to antigen antibody reaction will not occur.

AB^+ blood group is the universal recipient as it has no natural antibodies against ABO blood group (neither '*a*' nor '*b*' antibodies) in its blood and hence antigen antibody reaction will not occur and RBCs will not stick to each other.

BLOOD BANK

The blood bank is a place where blood of the voluntary donors is kept intact or preserved for future use. However, the stored blood must be used within 30 days.

Erythroblastosis Foetalis: Rh blood grouping carries significant importance during pregnancy. If an Rh –ve girl gets married to an Rh +ve male, she may carry a child with Rh +ve blood. The blood of child when mixes with mother's blood causes the mother's body to form antibodies against Rh factor. *The first Rh +ve child, however, is normal.* Now, if the mother conceives another Rh +ve child, the antibodies formed in her body after the first pregnancy can attack the blood of the foetus. It can lead to severe anaemia which can also cause death of the child. This abnormal condition is called **erythroblastosis foetalis**.

TISSUE FLUID AND LYMPH

When the blood flows in capillaries; some amount of water, proteins, blood cells and dissolved solutes are filtered out into the tissue spaces through the capillary wall. This forms the **tissue fluid** or **interstitial fluid**. As tissues are directly bathed in this fluid, the cells easily absorb oxygen and other substances from the fluid while releasing carbon dioxide and waste substances into it.

The composition of the tissue fluid is very similar to that of blood plasma, except that it **has lesser amount of proteins**. This is because of the impermeability of the capillary wall to large-sized plasma protein molecules.

Some of the tissue fluid is reabsorbed into the blood vessels, but most of it enters the other small channels called **lymph vessels**. The fluid within the lymph vessels is known as **lymph**.

Lymph

- Lymph is a **straw-coloured fluid** that flows in the lymph vessels due to the contraction of the surrounding muscles.

- It flows only in one direction, that is, *from the tissues towards the heart.*
- The lymph vessels are associated with **lymph glands** and **lymph nodes**. The small lymph vessels unite to form large lymph vessels, which finally drain into still larger lymph vessels. These, then, open into the veins and return the lymph into the circulatory system.
- Lymph consists of
  - ❑ white blood cells, mostly lymphocytes;
  - ❑ 94% water; and
  - ❑ 6% solid substances such as small amount of fats, carbohydrates, enzymes and proteins.

FUNCTIONS OF LYMPH

- ❑ **Absorption:** Lymph present in the lacteals of villi absorbs fats from the small intestine and transfers them to the blood. It also helps in the reabsorption of important substances into the blood from the interstitial fluid.
- ❑ **Carrier:** It carries plasma proteins, synthesised by the liver to the blood.
- ❑ **Nutrition:** It supplies nutrition and oxygen to the parts where blood cannot reach.
- ❑ **Defence:** Lymph contains lymphocytes and monocytes. These cells defend the body against germs and infections.
- ❑ **Prevents Spread of Infections:** The lymph nodes localise the infections and prevent them from spreading to other parts of the body, for example, lymph nodes in our armpits and the tonsils.

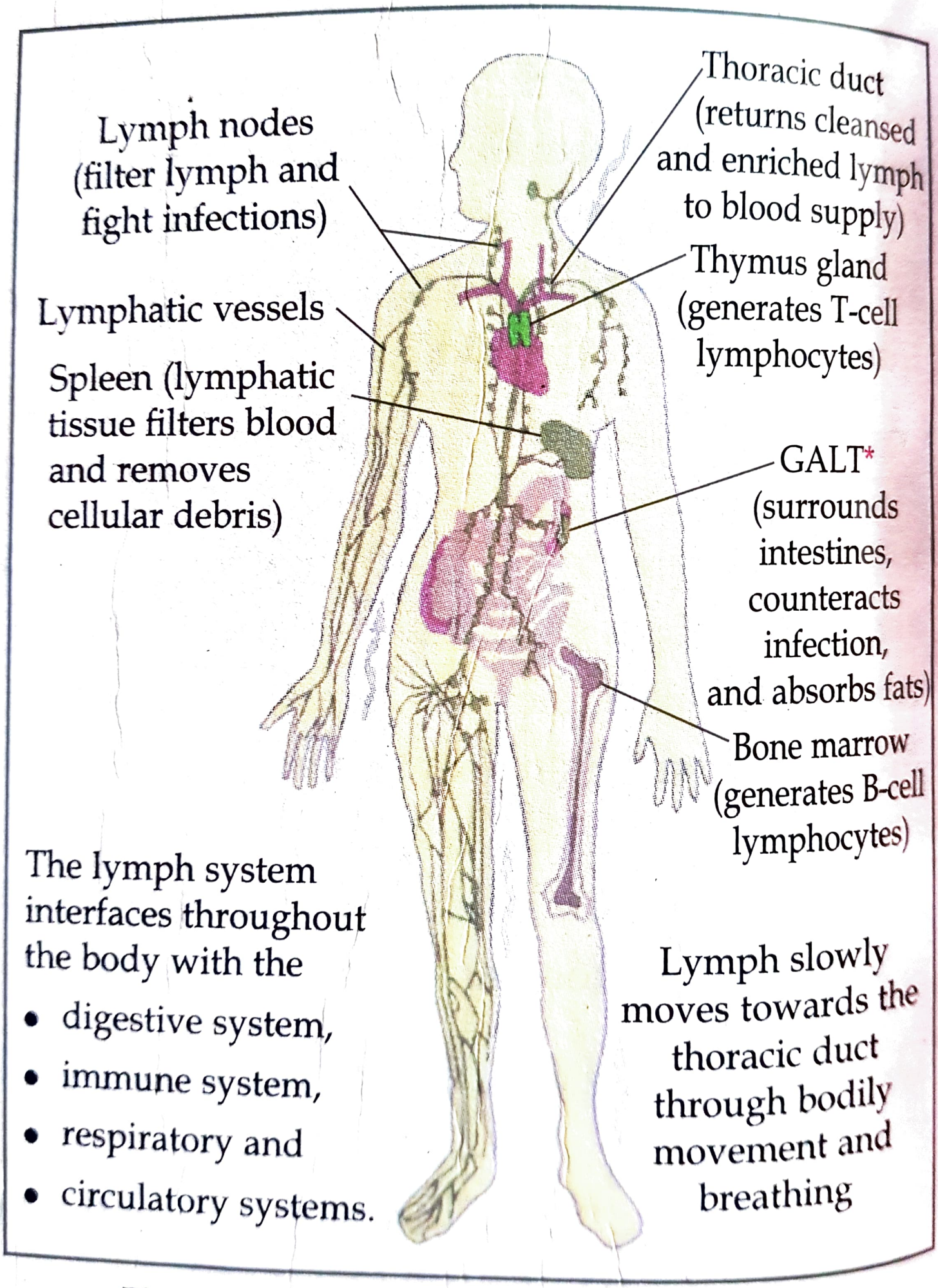


Fig. 8A.8: Lymphatic system in human body

* Gut-associated lymphoid tissue

Name the three kinds of fluids present in our body. Write one characteristic feature of each.

List the various substances which are transported by blood in our body.

Write whether the following statements are *true* or *false*. If *false*, correct the statement.

(*a*) Tissue fluid is present in the intracellular spaces of various organs.

(*b*) Blood is a fluid connective tissue with an alkaline pH.

Name the compound present in the blood which combines with respiratory gases for their transport.

Write the functions of plasma proteins present in the blood.

Name the following:

(*a*) Plasma protein that provides immunity.

(*b*) A protein without which plasma cannot clot.

(*c*) Two pigments formed by destruction/ breakdown of haemoglobin.

How does the biconcave shape of erythrocytes makes them efficient carriers of oxygen?

Write whether the following statements are *true* or *false*. If *false*, correct the statement.

(*a*) Foetal RBCs are nucleated while mature RBCs are enucleated.

(*b*) Formed elements constitute 40–45% of blood.

RBCs are efficient carriers of oxygen but still cannot respire aerobically. Give reasons.

Differentiate between anaemia and polycythemia.

Which characteristic feature of leucocytes helps them to pass through blood capillaries?

Name the following:

(*a*) Leucocyte which stains with acidic dyes.

(*b*) Smallest leucocyte in human blood.

(*c*) Reddening of an injured area because of release of histamines.

Write whether the following statements are *true* or *false*. If *false*, correct the statement.

(*a*) Thrombocytes are the only non-nucleated blood cells.

(*b*) Leucocytes are the most numerous cells in human blood.

Match the following:

Column A	*Column B*
(*a*) Basophils	(*i*) Platelets
(*b*) Lymphocytes	(*ii*) Allergy
(*c*) Eosinophils	(*iii*) Pus
(*d*) Dead WBCs	(*iv*) Histamine
(*e*) Blood clot	(*v*) Immunity

Which organs of our body are responsible for formation of blood cells?

What is the importance of blood group test before transfusion of blood?

Write whether the following statements are *true* or *false*. If *false*, correct the statement.

(*a*) Blood clot is formed by the entrapment of red and white blood cells.

(*b*) Antigens are present on the surface of blood cells and antibodies are present inside the blood cells.

What would happen if:

(*a*) An Rh –ve mother who first gave birth to an Rh +ve child conceives a second child with Rh –ve blood?

(*b*) An individual with AB blood group receives blood from an individual with B blood group?

(*c*) An individual with O blood group receives blood from an individual with AB blood group?

(*d*) Blood is devoid of Ca^{2+} ions?

(*e*) Blood is mixed with sodium oxalate?

Name the cells present in the lymph. What is the function of these cells?

How is lymph different from the interstitial fluid?

Write whether the following statements are *true* or *false*. If *false*, correct the statement.

(*a*) Lymph nodes prevent the infections to reach other organs.

(*b*) Digested fats present in the small intestine are absorbed in the lymph.