Body Fluids and Circulation - Part 2

Objectives

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

- Different types of blood groups
- Rh factor
- Importance and mechanism of coagulation of blood
- Lymph
- Circulatory pathways

Content Outline

- Introduction
- Blood Groups
  - Blood groups types
  - A, B, AB and O
- Rh factor
- Coagulation of blood
  - Importance and mechanism
- Lymph
- Circulatory pathways
- Summary

Introduction

As discussed earlier blood is the most important fluid of the body which performs the functions of transportation of nutrients, nitrogenous wastes, respiratory gases, hormones, intermediate metabolites, water and heat from one region to another region of our body. It flows through vessels and capillaries to and fro heart and body cells and tissue. The human blood consists of the components, Red blood cells, White blood cells, Plasma and Platelets.

The red blood cells are the ones that give blood its identity or 'type.' The ABO system is the principal blood grouping system used for humans which categorizes people into one of the following four groups – A, B, AB, or O. RhD is the second most important blood group system, after ABO, and it consists of 50 defined blood-group antigens, among which the five

antigens D, C, c, E, and e are the most important. The commonly used terms *Rh factor*, *Rh positive* and *Rh negative* refer to the *D antigen* only.

Coagulation (also known as **clotting**) is the process by which blood changes from a liquid to a gel, forming a blood clot. It potentially results in hemostasis, the cessation of blood loss from a damaged vessel, followed by repair. The mechanism of coagulation involves activation, adhesion, and aggregation of platelets along with deposition and maturation of fibrin.

Lymph is an alkaline fluid that originates as interstitial fluid in our body. It is a transparent, usually slightly yellow, often opalescent liquid found within the lymphatic vessels, and collected from tissues in all parts of the body and returned to the blood via the lymphatic system. It is about 95 percent water; the remainder consists of plasma proteins and other chemical substances contained in the blood plasma, but in a slightly smaller percentage than in plasma. Its cellular component consists chiefly of lymphocytes.

Blood Groups

Blood is made up of red blood cells, white blood cells and platelets in a liquid called plasma. Our blood group is identified by antibodies and antigens in the blood. Antibodies are proteins found in plasma. They're part of our body's natural defences. They recognise foreign substances, such as germs, and alert your immune system, which destroys them. Antigens are protein molecules found on the surface of red blood cells.The surface of a red blood cell is coated with a combination of sugars and proteins called antigens. Depending on your combination, you will have A antigens, B antigens, no antigens or both A and B antigens. It is the presence of the A and B antigens and corresponding antibodies in the clear part of blood called **plasma,** that determines an individual's blood group.

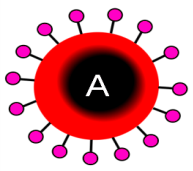
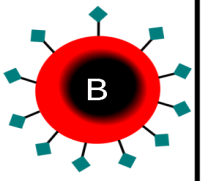
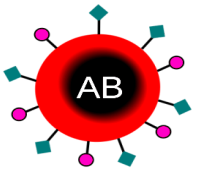
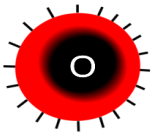
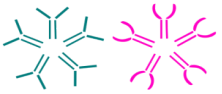
Antibodies are the body's natural defence system. They recognise any 'foreign' antigens and inform your immune system to destroy them. The antibodies found in plasma are unusual in that they are 'naturally occurring' meaning they don't need a stimulus such as a transfusion or pregnancy to be created. The *ABO system* is the most important blood-group system in human-blood transfusion. The associated anti-A and anti-B antibodies are usually *immunoglobulin M*, (***IgM***), antibodies.

The ABO system

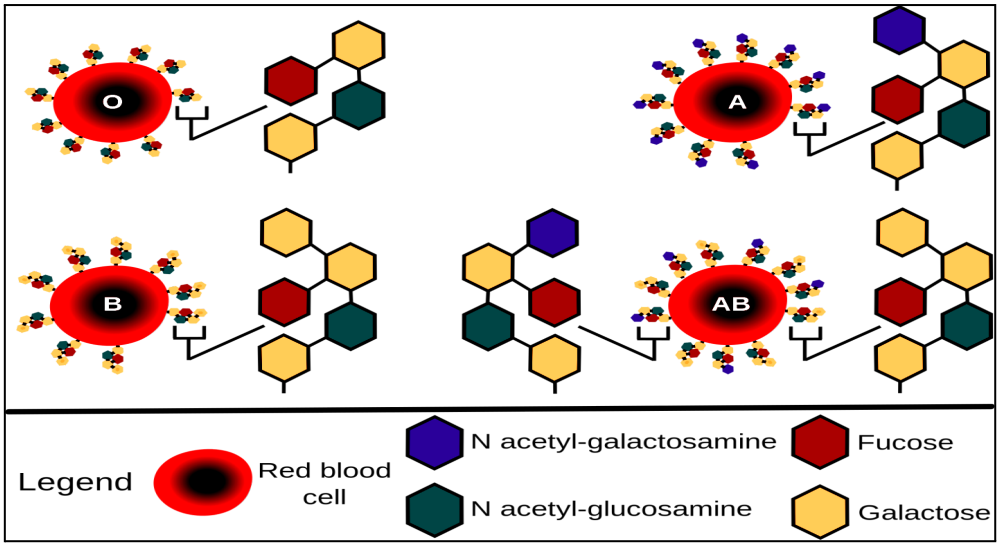
There are four main blood groups defined by the ABO system:

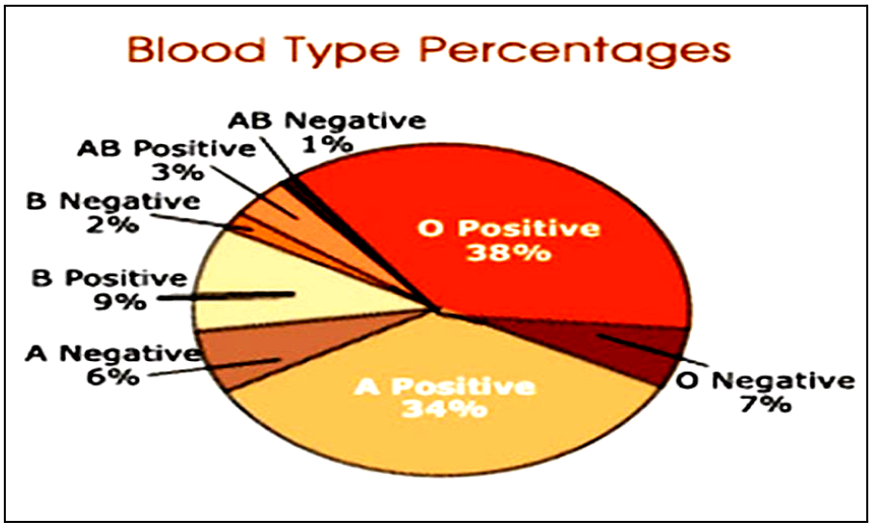
- **Blood group A –** has A antigens on the red blood cells with anti-B antibodies in the plasma
- **Blood group B** – has B antigens with anti-A antibodies in the plasma
- **Blood group O** – has no antigens, but both anti-A and anti-B antibodies in the plasma
- **Blood group AB** – has both A and B antigens, but no antibodies

There is an agglutination reaction between similar antigen and antibody (for example, antigen A agglutinates the antibody A and antigen B agglutinates the antibody B). Thus, transfusion can be considered safe as long as the serum of the recipient does not contain antibodies for the blood cell antigens of the donor.If a patient with blood group B received a transfusion from a donor with blood group A, their anti-A antibodies would attack the group A cells transfused to them. This is why group A blood must never be given to a group B person and vice versa. Giving someone blood from the wrong ABO group can be life-threatening.

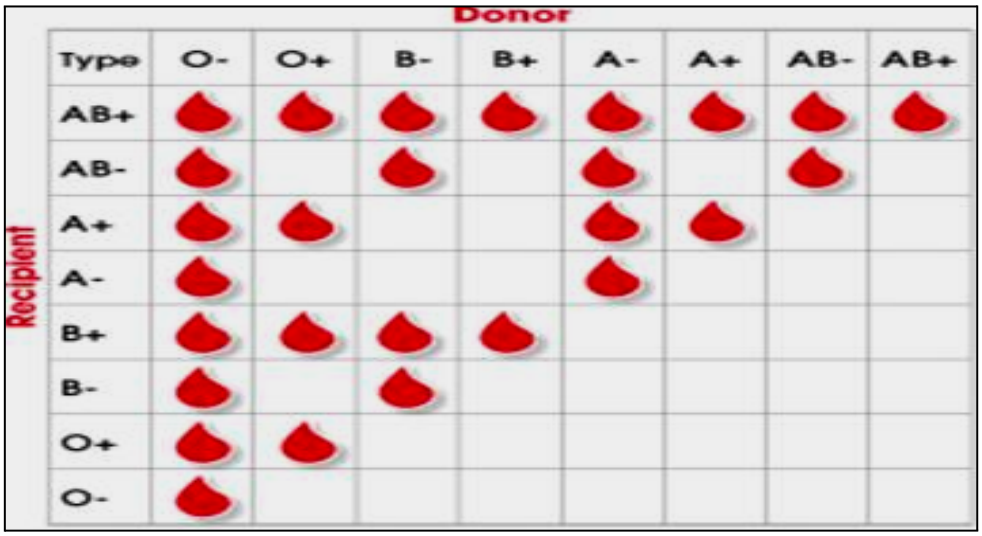
	Group A	Group B	Group AB	Group O
Red blood cell type				
Antibodies in Plasma	 Anti-B	 Anti-A	None	 Anti-A and Anti-B
Antigens in Red Blood Cell	 A antigen	 B antigen	 A and B antigens	None

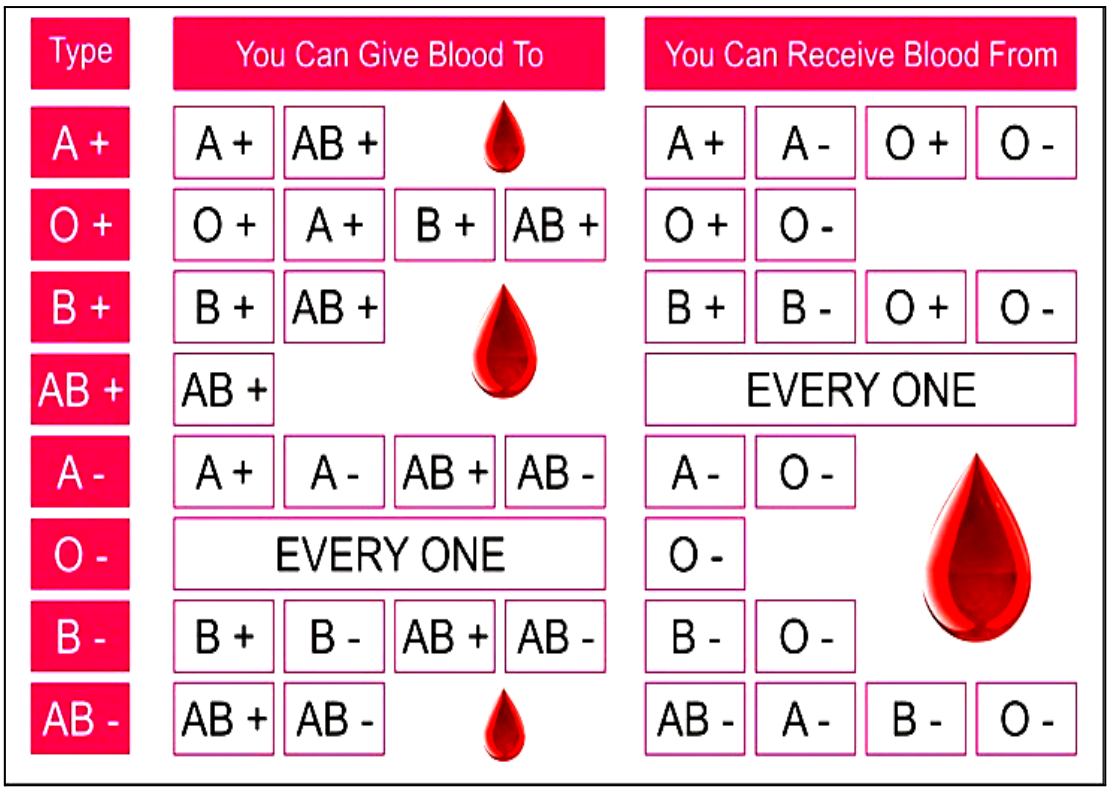
Blood group O has neither A nor B antigens on the surface of its red cells so the antibodies in groups A, B and AB do not identify it as foreign when transfused. This is why blood group O is often referred to as the ‘universal red cell'.Group AB has no anti-A or anti-B antibodies so does not identify the antigens on the surface of blood groups A, B or O as foreign. This means that patients with group AB blood can receive donations from groups A, B and O.





Blood Transfusion





Importance of Knowing Blood Groups

An individual's blood differs from that of the other due to types of substances on the red blood cells. These substances are called antigens. We also know that there are antibodies in our plasma. These antibodies do not react to our own tissues but react with antigens on the red blood cells of another person. Thus, we can group people on the basis of their antigens and antibodies into four groups: A, B, O and AB. People whose blood is A have antigen A and carry antibody B. Group B people have antigen B and antibody A. Group O people do not have either antigen A or antigen B but both antibodies are present.

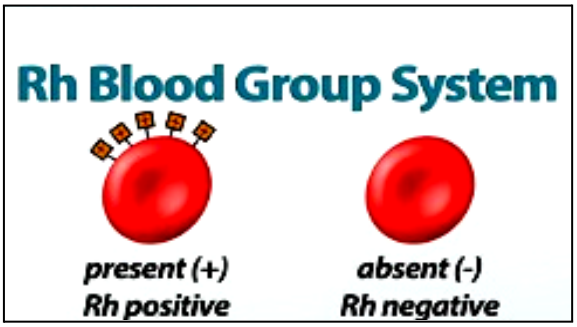
When blood is given to the patient (blood transfusion), it will be dangerous if the recipient patient gets blood with antigen against which he has antibodies. This will clump the red blood cells, transfused from the donor, the person who gives blood. This is a serious reaction. Thus, it is vitally important to know blood groups of both the donor and the recipient belong to group A, he will not be able to receive blood from group B donors. In this case, which blood groups can be safely received? Same blood groups can be transferred.

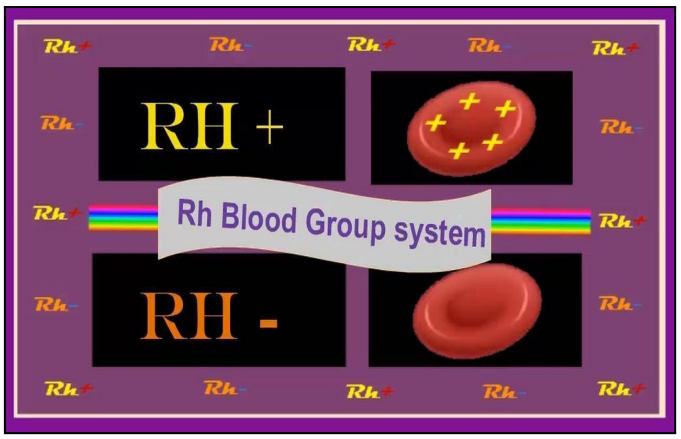
Rh Blood Group System

The **Rh factor** is simply a red blood cell antigen - just like the A antigen and the B antigen that are used to determine your blood type. The Rh factor is named after the Rhesus monkey, which is the animal where it was first identified. The Rh factor is important when we learn about the **Rh blood group system**. The Rh blood group system is a classification system for blood that depends on the presence or absence of the Rh antigen - or factor - on our red blood cells. In other words, we were either born with the Rh factors on our red blood cells, like most people, or we were born without them, which is more rare. Since the Rh factor can be either present (+) or absent (-), we refer to people as being either Rh positive if they have the Rh factor, or Rh negative if they do not.

We previously learned that in the ABO blood group system that antibodies are automatically produced based on antigens not present on our red blood cells. In the Rh blood group system, the antibodies are not automatically produced. Instead, a person with Rh negative blood needs to be 'sensitized' before he or she will start to produce antibodies to the Rh antigen. Let's look at an example.

If a woman with Rh negative blood who has never had a blood transfusion or any other gets exposure to anyone else's blood, she will not have any antibodies against the Rh antigen. It's almost like her body doesn't even care which Rh blood group she belongs to. However, if this woman gets a bad blood transfusion that contains Rh positive blood, her body will now be 'primed,' or 'sensitized,' to the Rh positive antigen and start to produce anti-Rh positive antibodies. Because this was the first exposure, there's no real harm done, other than the fact that now she has the antibodies floating around in her bloodstream. The only significant point is that because the antibodies are now in her bloodstream, she can never again come in contact with Rh positive blood or her antibodies will attack.





Blood Clotting (Coagulation)

Importance:

Why Does Blood Clot?

The blood clots occur primarily in order to prevent excessive bleeding.

Think about it. In the early days of humankind, before Band-Aids, gauze, and stitches, our bodies needed a mechanism by which to prevent massive blood loss. Though deep wounds could often be deadly (and still are, today) we needed protection from minor cuts and abrasions without blood clots, these minor injuries could be enough to make us bleed to death.

For this reason, cuts and other wounds that cause bleeding are the most common causes of blood clots. Once the blood clot has achieved its mission of preventing excessive bleeding, it must stop growing and be prevented from spreading through the body and causing damage.

Blood coagulation refers to the process of forming a clot to stop bleeding. To stop bleeding, the body relies on the interaction of three processes:

Primary hemostasis involves the first two processes.

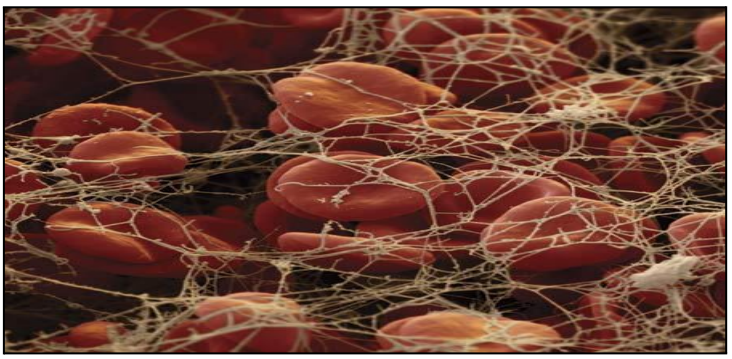
- **Vasoconstriction.** Vasoconstriction is the body's first response to injury in the vascular wall. When injury occurs, vessel walls constrict, causing reduced blood flow to the site of injury.
- **Platelet plug.** Platelets aggregate to the site of the injury. They stick together acting as a "plug." Platelets also activate the process which causes a fibrin clot to form, known as secondary hemostasis.

Secondary hemostasis.

- **Platelets alone are not enough to secure the damage in the vessel wall.** A clot must form at the site of injury. The formation of a clot depends upon several substances called clotting factors. These factors are designated by roman numerals I through XIII. These factors activate each other in what is known as the clotting cascade. The end result of this cascade is that fibrinogen, a soluble plasma protein, is cleaved into fibrin, an insoluble plasma protein.The fibrin proteins stick together forming a clot.

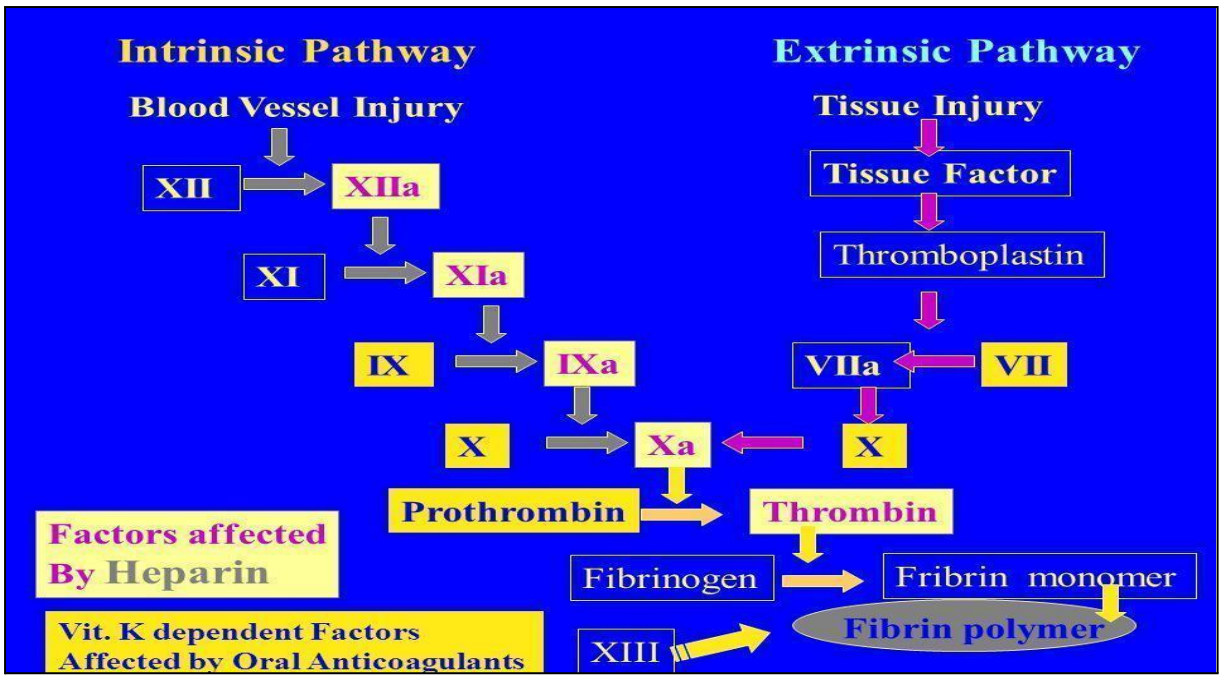
Mechanism

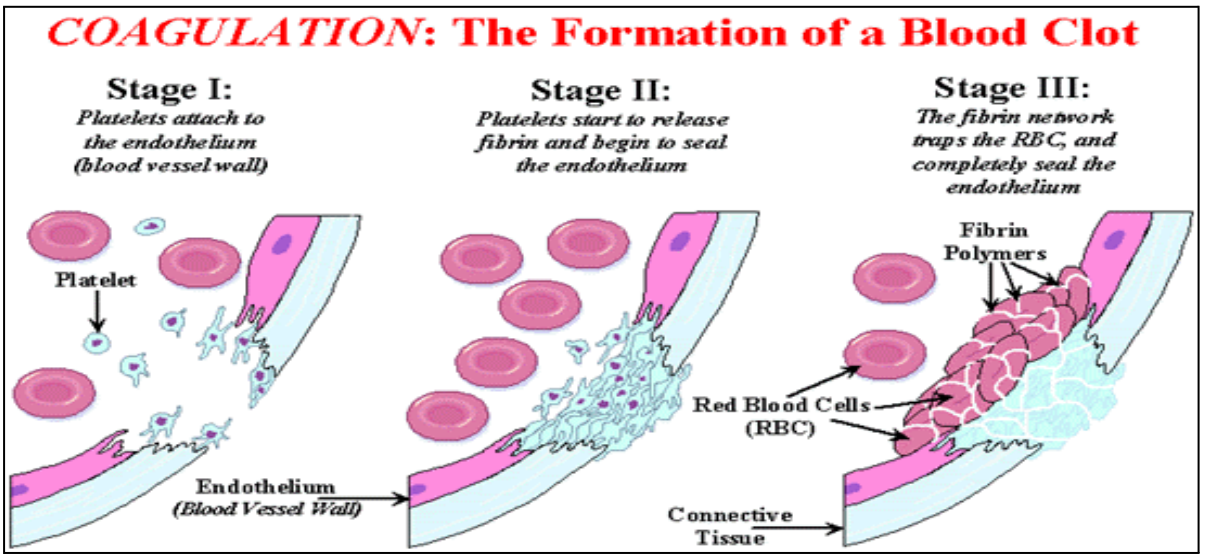
Blood exhibits coagulation or clotting in response to an injury or trauma. This is a mechanism to prevent excessive loss of blood from the body. You would have observed a dark reddish brown scum formed at the site of a cut or an injury over a period of time. It is a clot or coagulam formed mainly of a network of threads called fibrins in which dead and damaged formed elements of blood are trapped. Fibrins are formed by the conversion of inactive fibrinogens in the plasma by the enzyme thrombin. Thrombins, in turn, are formed from another inactive substance present in the plasma called prothrombin. An enzyme complex, thrombokinase, is required for the above reaction. This complex is formed by a series of linked enzymatic reactions (cascade process) involving a number of factors present in the plasma in an inactive state. An injury or a trauma stimulates the platelets in the blood to

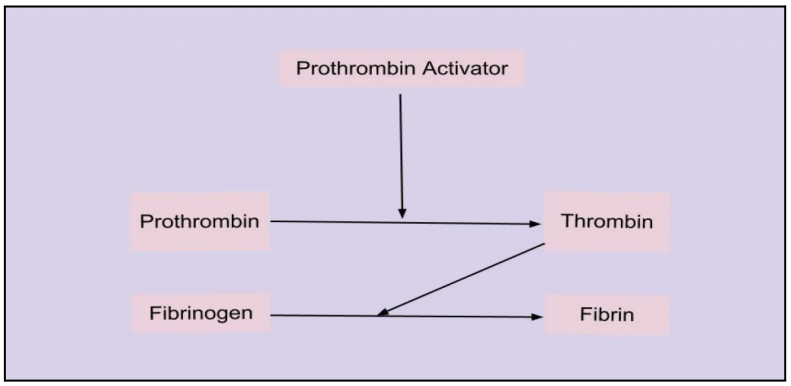


release certain factors which activate the mechanism of coagulation. Certain factors released by the tissues at the site of injury also can initiate coagulation. Calcium ions play a very important role in clotting.

As the damaged tissue heals, the body slowly dissolves the blood clot and reabsorbs it over the course of several weeks by using an enzyme called plasmin and other substances.


Intrinsic Pathway
Blood Vessel Injury
XII
XIIa
XI
XIa
IX
IXa
X
Xa
Prothrombin
Thrombin
Fibrinogen
Fribrin monomer
Fibrin polymer
XIII
Extrinsic Pathway
Tissue Injury
Tissue Factor
Thromboplastin
VIIa
VII
X
Factors affected By Heparin
Vit. K dependent Factors Affected by Oral Anticoagulants


COAGULATION: The Formation of a Blood Clot
Stage I:
Platelets attach to the endothelium (blood vessel wall)
Stage II:
Platelets start to release fibrin and begin to seal the endothelium
Stage III:
The fibrin network traps the RBC, and completely seal the endothelium
Platelet
Endothelium
(Blood Vessel Wall)
Fibrin Polymers
Red Blood Cells (RBC)
Connective Tissue


Prothrombin Activator
Prothrombin
Thrombin
Fibrinogen
Fibrin

Lymph

Lymph is the fluid that circulates throughout the lymphatic system. The lymph is formed when the interstitial fluid (the fluid which lies in the interstices of all body tissues) is collected through lymph capillaries. It is then transported through larger lymphatic vessels to lymph nodes, where it is cleaned by lymphocytes, before emptying ultimately into the right or the left subclavian vein, where it mixes back with the blood.

Composition

Lymph has a composition comparable to that of blood plasma, but it may differ slightly. Lymph contains white blood cells. In particular, the lymph that leaves a lymph node is richer in lymphocytes. Likewise, the lymph formed in the human digestive system called chyle is rich in triglycerides (fat), and looks milky white because of its lipid content.

Formation

Blood supplies nutrients and important metabolites to the cells of a tissue and collects back the waste products they produce, which requires exchange of respective constituents between the blood and tissue cells. This exchange is not direct, but instead is affected through an intermediary called *interstitial fluid* or *tissue fluid*, the fluid that occupies the spaces between the cells and constitutes their immediate environment. As the blood and the surrounding cells continually add and remove substances from the interstitial fluid, its composition continually changes. Water and solutes can pass between the interstitial fluid and blood via diffusion across gaps in capillary walls called intercellular clefts; thus, the blood and interstitial fluid are in dynamic equilibrium with each other.

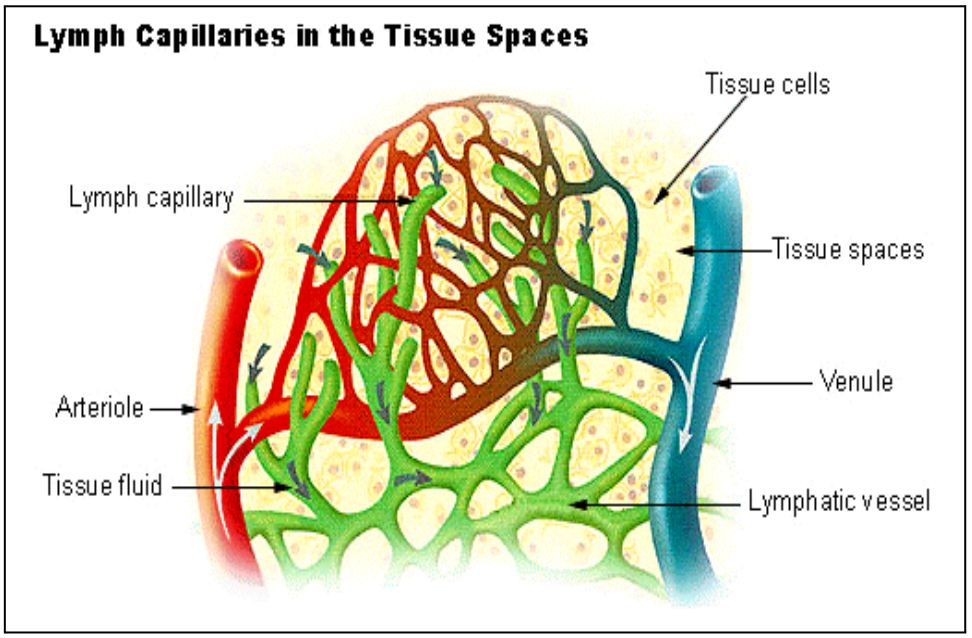
Interstitial fluid forms at the arterial (coming from the heart) end of capillaries because of the higher pressure of blood compared to veins, and most of it returns to its venous ends and venules; the rest (up to 10%) enters the lymph capillaries as lymph. Thus, lymph when formed is a watery clear liquid with the same composition as the interstitial fluid. However, as it flows through the lymph nodes it comes in contact with blood, and tends to accumulate more cells (particularly, lymphocytes) and proteins.

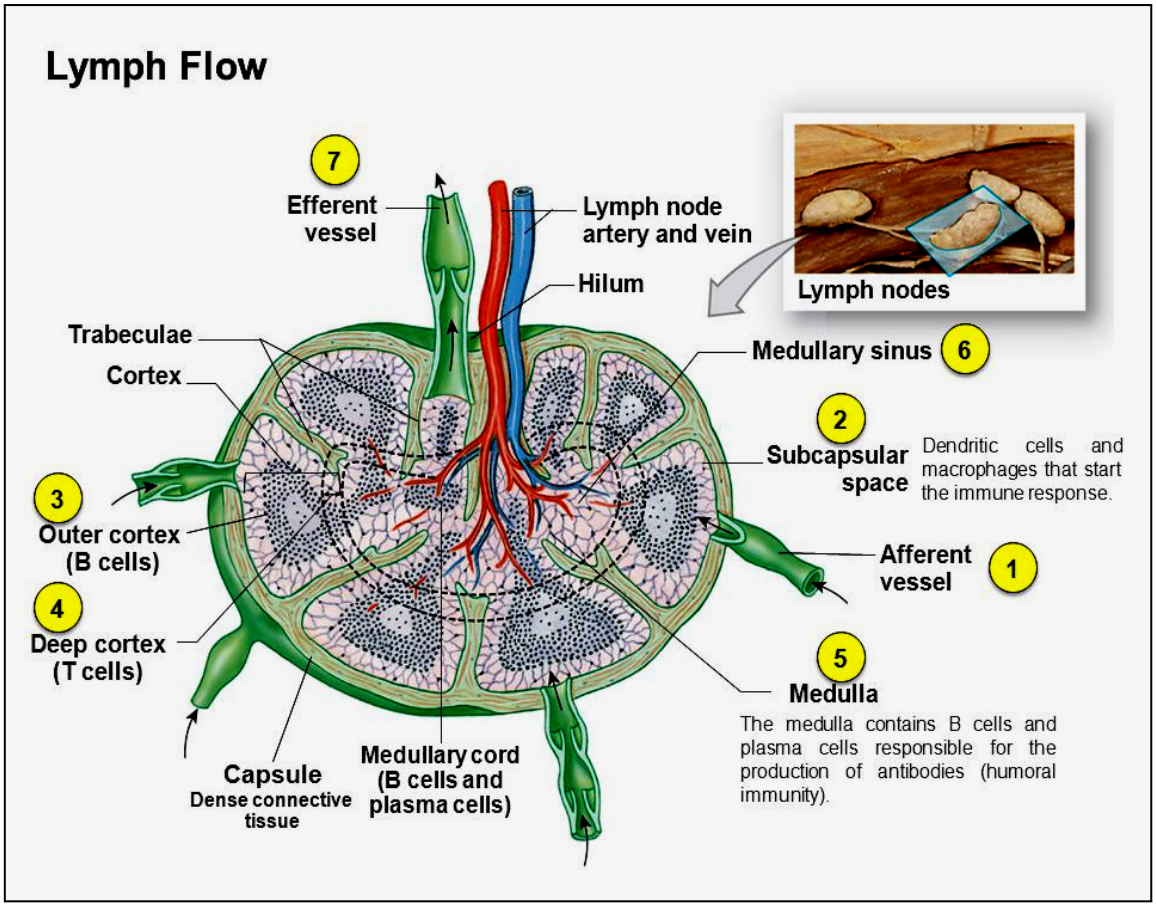
Lymph Circulation

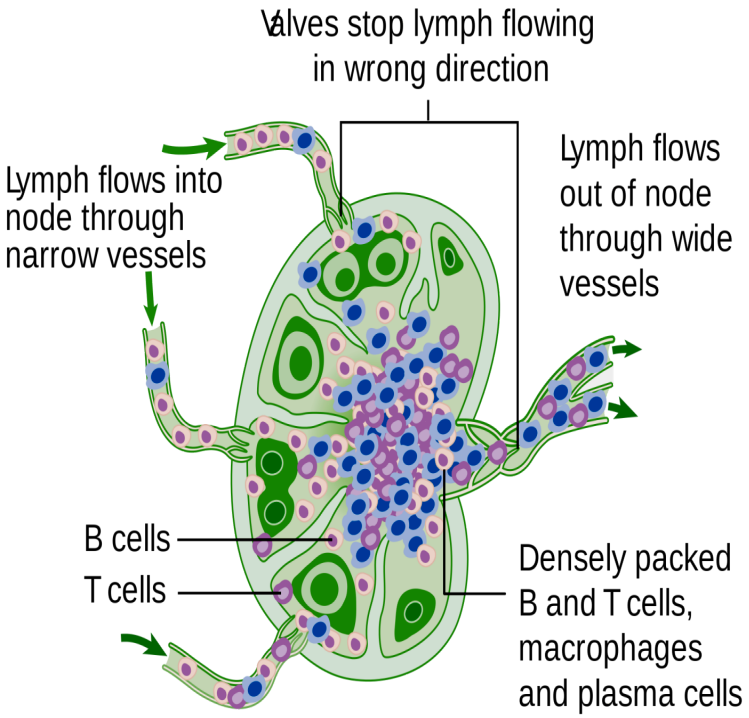
Tubular vessels transport lymph back to the blood, ultimately replacing the volume lost during the formation of the interstitial fluid. These channels are the lymphatic channels, or simply lymphatics.

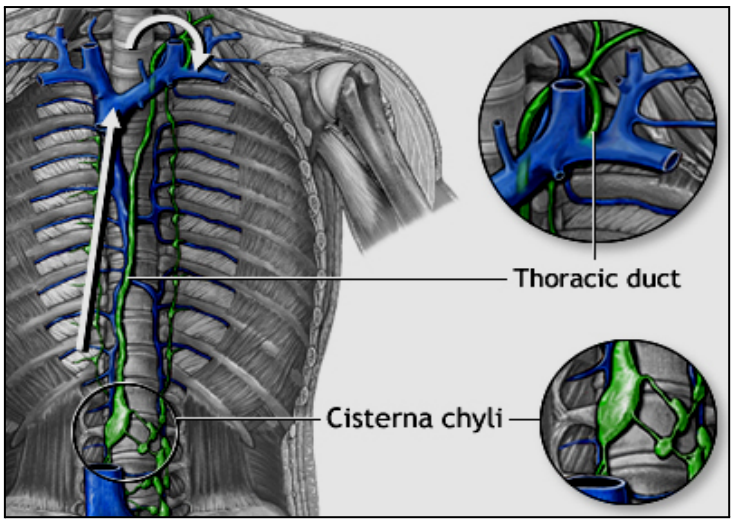
Unlike the cardiovascular system, the lymphatic system is not closed and has no central pump, or lymph hearts (which are found in some animals). Lymph transport, therefore, is slow and sporadic. Despite low pressure, lymph movement occurs due to peristalsis (propulsion of the lymph due to alternate contraction and relaxation of smooth muscle tissue), valves, and compression during contraction of adjacent skeletal muscle and arterial pulsation.

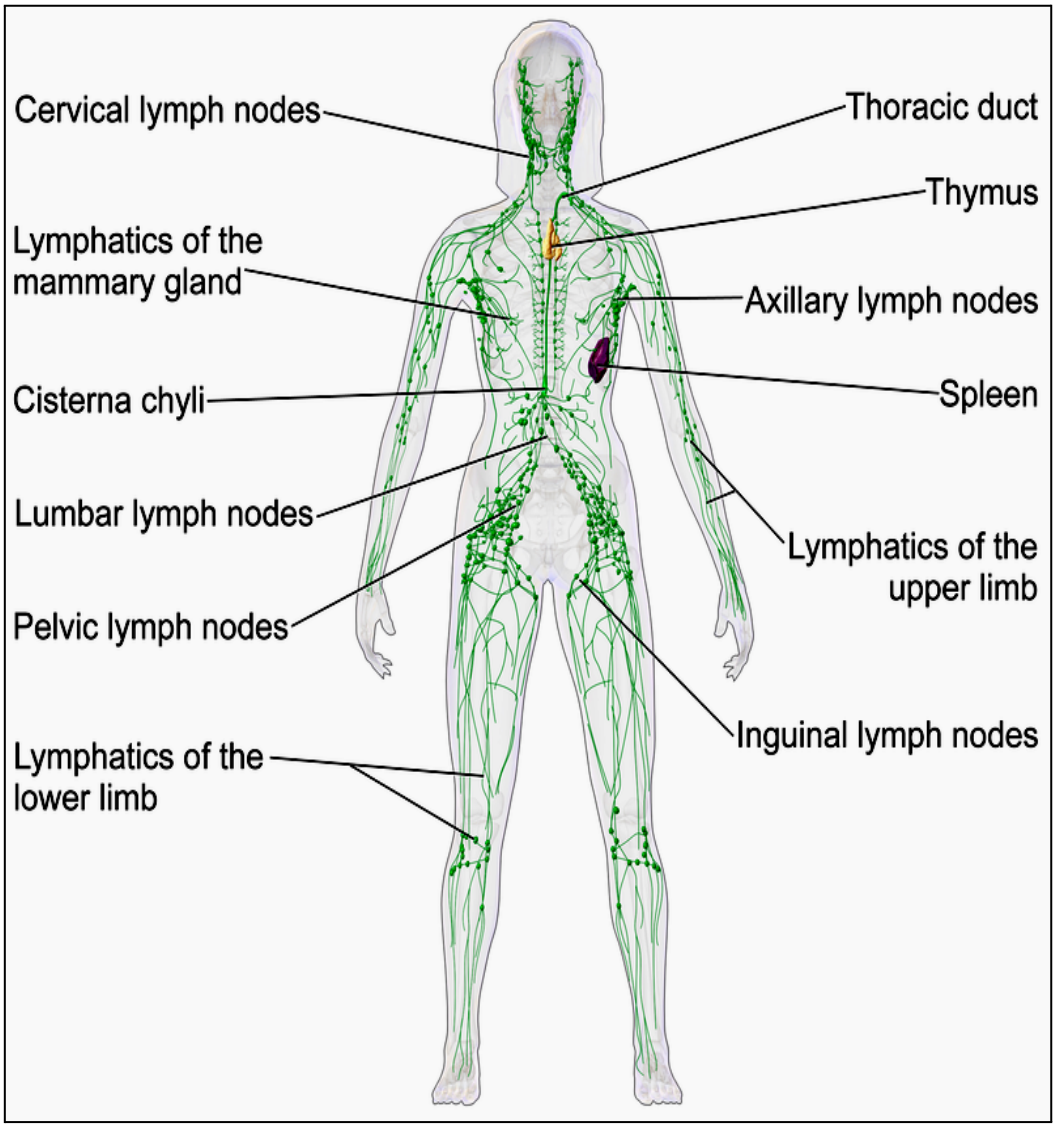
Lymph that enters the lymph vessels from the interstitial spaces usually does not flow backwards along the vessels because of the presence of valves. If excessive hydrostatic pressure develops within the lymph vessels, though, some fluid can leak back into the interstitial spaces and contribute to formation of oedema. Flow of the lymph in the thoracic duct in an average resting person usually approximates 100ml per hour. Accompanied by another ~25ml per hour in other lymph vessels, total lymph flow in the body is about 4 to 5 liters per day. This can be elevated several folds while exercising. Thus, it can be estimated that without lymphatic flow, an average resting person would die within 24 hours.

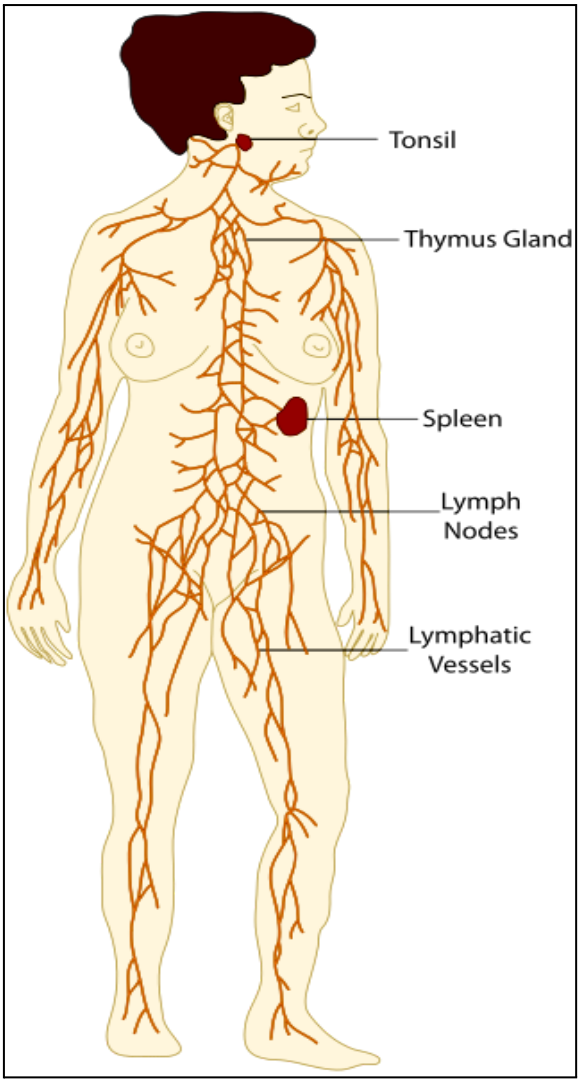



Lymph Flow
7
Efferent vessel
Lymph node artery and vein
Hilum
Lymph nodes
Trabeculae
Cortex
Medullary sinus
6
2
Subcapsular space
Dendritic cells and macrophages that start the immune response.
3
Outer cortex (B cells)
Afferent vessel
1
4
Deep cortex (T cells)
5
Medulla
The medulla contains B cells and plasma cells responsible for the production of antibodies (humoral immunity).
Capsule
Dense connective tissue
Medullary cord (B cells and plasma cells)


Valves stop lymph flowing in wrong direction
Lymph flows into node through narrow vessels
Lymph flows out of node through wide vessels
B cells
T cells
Densely packed B and T cells, macrophages and plasma cells


Thoracic duct
Cisterna chyli

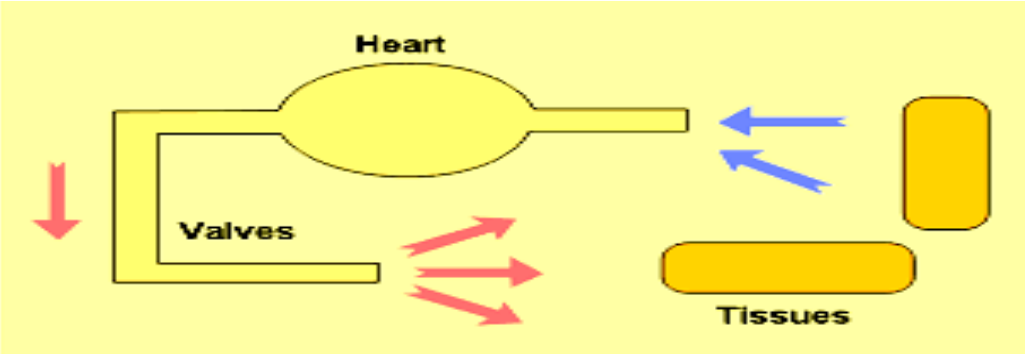

Cervical lymph nodes
Thoracic duct
Thymus
Lymphatics of the mammary gland
Axillary lymph nodes
Cisterna chyli
Spleen
Lumbar lymph nodes
Lymphatics of the upper limb
Pelvic lymph nodes
Inguinal lymph nodes
Lymphatics of the lower limb



Circulatory Pathways

The circulatory patterns are of two types – **open or closed**. Open Circulatory System:

In an open circulatory system, blood pumped by the heart passes through large vessels and drains into open spaces or body cavities; called sinuses. This type of circulatory system is present in arthropods and molluscs.



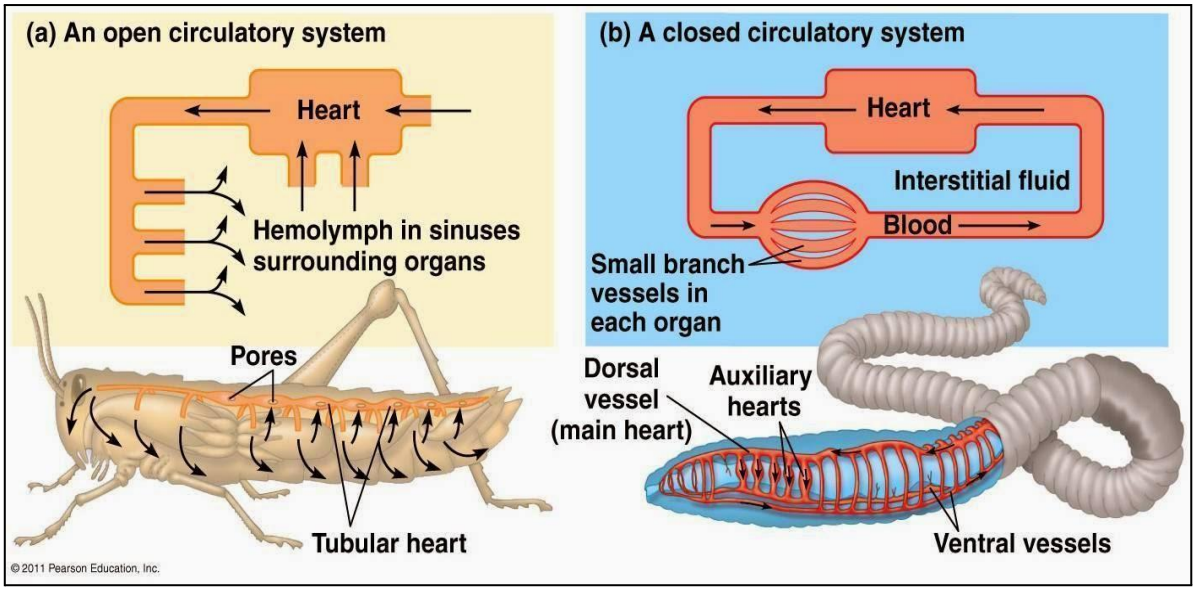
Closed Circulatory System: In a closed circulatory system blood pumped by the heart is circulated through a closed network of blood vessels. This type of system is present in annelids and chordates. The closed circulatory system is more advantageous because the flow of fluid can be more precisely regulated.

Chambered Heart: A muscular chambered heart is present in all vertebrates. The fishes have a 2-chambered heart; with an atrium and a ventricle. Amphibians and reptiles have a 3-chambered heart; with two atria and one ventricle. But crocodiles have 4-chambered heart. Birds and mammals have 4-chambered heart; with two atria and two ventricles.

Single Circulation: In fishes, the heart pumps out deoxygenated blood to the gills. The oxygenated blood from the gills is supplied to the body parts. Deoxygenated blood is then returned from different body parts to the heart. In single circulation, the blood passes through the heart only once.

Incomplete Double Circulation: In amphibians and reptiles, incomplete double circulation is present. Oxygenated blood is received by the left atrium and deoxygenated blood is received by the right atrium. But, both the bloods get mixed up in the single ventricle which pumps out the mixed blood. In incomplete double circulation, the blood comes to the heart through two different routes, but goes out through a single route.

Complete Double Circulation: Complete double circulation is present in birds and mammals. In this case, the oxygenated blood is received by the left atrium and the deoxygenated blood is received by the right atrium. The oxygenated blood is pumped out through the left ventricle, while the deoxygenated blood is pumped out through the right ventricle. In complete double circulation, there are two separate pathways for oxygenated and deoxygenated bloods.



Summary

Blood is an important fluid of our body which performs the functions of transportation of nutrients, nitrogenous wastes, respiratory gases, hormones, intermediate metabolites, water and heat from one region to another region of our body. Blood of humans are grouped into A, B, AB and O systems based on the presence or absence of two surface antigens, A, B on the RBCs. Another blood grouping is also done based on the presence or absence of another antigen called Rhesus factor (Rh) on the surface of RBCs. The spaces between cells in the tissues contain a fluid derived from blood called tissue fluid. This fluid called lymph is almost similar to blood except for the protein content and the formed elements. In arthropods and mollusks an open type of circulatory system is present. All vertebrates and a few invertebrates have a closed circulatory system. Our circulatory system consists of a muscular pumping organ, heart, a network of vessels and a fluid, blood.