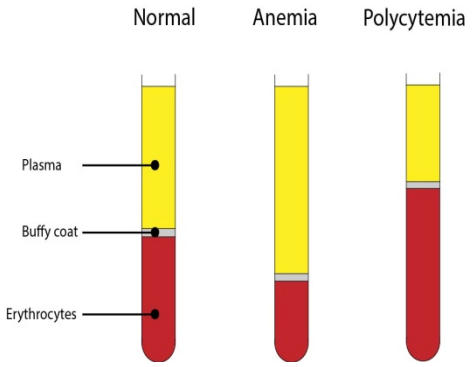
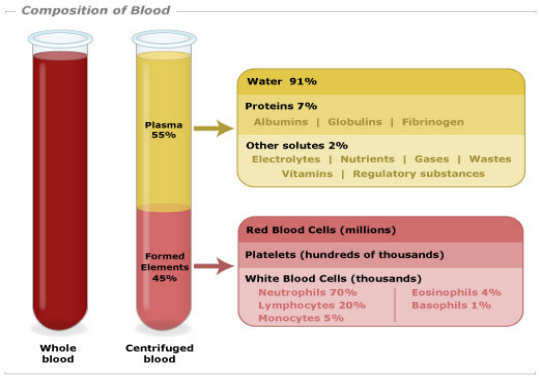
Circulatory media:

Composition of blood and its functions:

Blood is a suspension of blood elements (erythrocytes, leukocytes, and platelets) in blood plasma. Blood elements can be separated from blood plasma using centrifugal force. Figure shows that the most descended are erythrocytes – the volume of erythrocytes in a sample of blood is called the hematocrit. Hematocrit values differ depending on sex – in men the values range about 44 ± 5 % of blood volume and in women about 39 ± 4 % of blood volume. Above the erythrocyte layer is found the white non-transparent layer composed of leukocytes and thrombocytes. This layer is called buffy coat (forms about 1 % of blood volume).





In our blood vessels circulate about 4.5-6 l of blood, which represents approximately 6-9% of body weight. Women have less blood than men. Blood plasma, making up the liquidportion of blood, is a colloid solution of organic and inorganic substances (electrolytes, nutrients, proteins, hormones etc.) with an addition of dissolved blood gases. It is slightly opalescent and its pale yellowish colour is caused by the presence of pigments, formed by decay of erythrocytes. Volume of blood plasma is approximately 2.8-3.5 l (40-45 ml/kg of b.w.). Together with the lymph, it makes up to 25 % of extracellular fluid (ECF).

Basic functions of blood include:

1) Transport of nutrients, waste products, blood gases (oxygen and carbon dioxide) or signaling molecules
2) Immune function
3) To maintain homeostasis of water, ions or pH
4) Distribution of heat throughout the body
5) Blood clotting

Types of Circulation:

Open and Closed Circulatory System:

We all know that in all life forms the gases and nutrients are transported to all parts of the body. There is an

efficient transport system which carries all the activities of transportation in living beings. In unicellular organisms and small multicellular organisms, diffusion is the key process for transportation. Diffusion is a slow process. As distances are increased, diffusion no longer facilitates the transportation process as many of the cells are not exposed directly to the atmosphere. We need an elaborate and sophisticated transport system. Circulatory system is one of the most sophisticated transport systems in body. In circulatory system, a fluid circulates in body. Haemolymph and blood are the fluids which circulate in invertebrates and vertebrates' body respectively.

Characteristics of Circulatory System:

A circulatory system is the flow of materials from one part of the body to another part of the body. Following are the characteristics of circulatory system:
A fluid to circulate – blood or haemolymph
A pumping mechanism
Blood vessels in which blood or haemolymph flows

Circulatory system is categorized into two types:

- Open circulatory system
- Closed circulatory system

Open Circulatory System:

Open circulatory system is considered as primitive circulatory system because it is not capable of upholding blood pressure. In open circulatory system, Haemolymph or blood doesn't remain enclosed in the tubes or vessels and comes in direct contact with the body cells or tissues. The pumping machine, the heart pumps the haemolymph into the tubes and then the tubes vacant themselves into sinuses. These sinuses are open spaces and haemolymph directly comes in contact with tissues and transport nutrients. After bathing the cells and tissues, haemolymph again goes through the heart for the next circulation. During the bathing of cells, exchange of nutrients takes place*.

This system only transports nutrients. Gases are not transported by this system. Gases are transported by the tracheal system.

Closed Circulatory System:

Closed circulatory system is a sophisticated and elaborate system as compared to open circulatory system. In closed circulatory system, blood is restricted in the blood vessels during circulation. There is a unified system of arteries, veins and capillaries. Unlike open circulatory system, **closed circulatory system is capable of transporting gases.**

Arteries are the specialized tubes which take the blood away from away from the heart and **veins** are the dedicated vessels which bring back the blood from all parts of the body to heart. The pumping organ i.e. heart pumps the blood. Arteries take the blood from heart and carry it to tissues. For exchange of materials between blood and tissues, arteries divide and subdivide into very tiny and fine branches called capillaries. These one celled thick capillaries exchange nutrients between blood and tissues. The capillaries join and form bigger blood vessels called venules. These venules then form veins, which in the end bring back blood to heart.

The comparison between closed and open circulatory system is shown in following table:

Open Circulatory System	Closed Circulatory System
1. Blood isn't restricted to blood vessels. Blood is in direct contact with body tissues.	1. Blood is always restricted in blood vessels i.e. arteries, capillaries and veins.
2. There are no characteristic blood vessels. Haemolymph flows in sinuses of hoemocoel.	2. There is a sophisticated and unified system of arteries, capillaries and veins.
3. When blood is in direct contact with tissues, only	3. Through capillaries, nutrients and waste materials are

then exchange of materials takes place.	exchanged between tissues and blood by means of tissue fluid.
4. System doesn't support transport of gases.	4. Not only nutrients are transported, gases are also transported.
5. This system can't maintain blood pressure. There is no respiratory pigment dissolved in blood. It is white.	5. This system can maintain Blood Pressure. Haemoglobin, a respiratory pigment is present in blood.

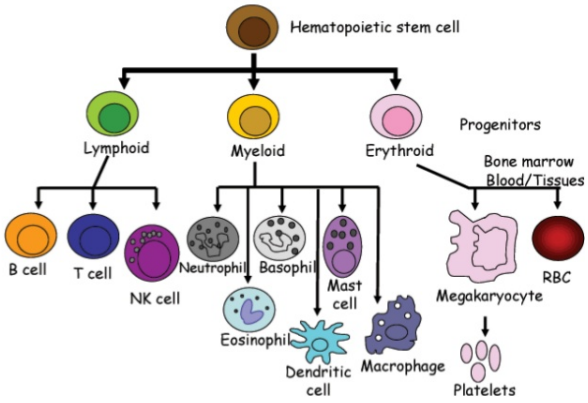
Hematopoiesis:

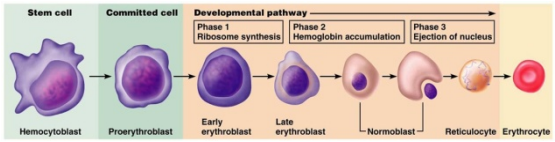
- Hematopoiesis refers to the process that generates new, mature blood cells. All such cells ultimately derive from a single progenitor cell termed the Hematopoietic Stem Cell (HSC) which undergoes a process of highly regulated division and differentiation that produces the gamut of mature blood cells. Although during fetal life hematopoiesis begins in the yolk sac followed by a phase in the liver and spleen, by birth and throughout adult life hematopoiesis takes place in the bone marrow.

- A large body of evidence supports the notion that all mature blood cells derive from a single cell type known as the "Hematopoietic Stem Cell" (HSC). As this cell divides, it's descendants begin to differentiate down particular pathways toward mature blood cells, akin to traveling from a tree trunk, down progressively thinner branches, toward a particular leaf. As these cells differentiate toward a particular cell type, they progressively lose their capacity to develop into the other cell types found in other branches of the differentiation tree.
- The overall architecture of this differentiation tree largely matches the basic categories of blood cells with pathways dedicated to making erythrocytes (**erythropoiesis**), lymphocytes (**lymphopoiesis**), granulocytes (**granulopoiesis**), monocytes (**monopoiesis**), and platelets (**thrombopoiesis**). Below we discuss these basic pathways and the intermediate cell types that define that differentiation pathway. An intimate understanding of these intermediate cell types is not necessary, but a broad understanding of the overall architecture of the differentiation tree may be helpful in appreciating the similarities and differences between mature blood cells.
- A final note: Hematopoiesis is a life-time activity and thus exhausting the supply of HSCs would be disastrous. Consequently, it is important to note that when a HSC divides, one daughter cell remains an HSC, while the other begins the process of differentiation, thus guaranteeing a lifetime supply of HSCs.

Erythropoiesis:

- Erythropoiesis refers to the process which generates fully mature erythrocytes and requires the synthesis of vast amounts of hemoglobin along with the ultimate loss of the cell's nucleus and intracellular organelles. The first recognizable cell type that is fully committed to differentiating into an erythrocyte is termed the "Proerythroblast", a large nucleus-containing cell with no hemoglobin and prominent organelles.
- As this cell differentiates, its size becomes progressively smaller, organelles are lost, and its color changes from blue (basophilic) to pink (eosinophilic), reflecting decreasing content of hemoglobin-coding nucleotides (blue), and increasing content of actual proteinaceous hemoglobin (pink). As differentiation proceeds, the nucleus becomes increasingly small, compact, and is ultimately extruded from the cell.
- The cells which exit the bone marrow and into the circulation are not fully mature and still contain a small amount of nucleotide content that renders them slightly basophilic. These "reticulocytes" can be easily observed in the peripheral blood, and elevated levels (termed "Reticulocytosis") is an important indication that erythropoiesis is increased within the marrow.
- The entire process of erythropoiesis is regulated by erythropoietin, a soluble protein synthesized by the kidneys in response to low arterial oxygen tension within the blood. Thus when the blood's oxygen tension is low, increased eyrthropoietin levels stimulate enhanced erythropoiesis which boosts the levels of erythrocytes in the blood and thus enhance the blood's oxygen carrying capacity.





Types of Anticoagulants:

What are Anticoagulants

Anticoagulants are medicines that reduce the ability of the blood to clot. There are a number of different types of anticoagulants, each with a different mechanism of action, although they all work by inhibiting various pathways of blood coagulation.

Anticoagulants may also be called "blood thinners"; however, they don't really thin the blood, just prolong the time it takes for your blood to clot. Anticoagulants are similar in their action to antiplatelets and thrombolytic drugs, which also act on coagulation pathways.

Anticoagulants are usually used to treat conditions with a high risk of blood clots such as atrial fibrillation, deep vein thrombosis (DVT), myocardial infarction (heart attack), pulmonary embolism, and stroke.

There are many anticoagulants, including:

- heparin
- warfarin (Coumadin)
- rivaroxaban (Xarelto)
- dabigatran (Pradaxa)
- apixaban (Eliquis)
- edoxaban (Savaysa)
- enoxaparin (Lovenox)
- fondaparinux (Arixtra)

Mechanism: Coagulation of blood is a complicated process in which about 13 coagulation factors are involved. All these factors are blood proteins or their derivatives. Even if one of the factor is defective, the whole clotting process is impaired leading to haemorrhage.These factors are from F-I to F-XIII.
Clotting mechanism begins by Trauma to tissues or trauma to blood.In each case it leads to formation of prothrombin activator which causes conversion of prothrombin in to thrombin. There are two pathways of formation of prothrombin activator.
i)Extrinsic Pathway: It begins with trauma to Vascular wall or to the tissues outside the blood vessel.
ii) Intrinsic pathway: It begins with trauma to blood itself

In both pathways, different blood clotting factors play important roles. Davie and Ratnoff (1965) have proposed a waterfall sequence hypothesis to explain the events taking place in coagulation process. Where as Macfarlane has suggested a scheme of coagulation called enzyme cascade which is similar to waterfall

sequence. Blood clotting factors exist in inactive form and are activated sequentially until finally prothrombin activator is formed. Extrinsic Mechanism (Factors involved – III-VII-X-V) for formation of prothrombin activator
1) It begins with trauma to blood vessel or tissues outside the blood vessel. It releases tissue factor and Tissue phospholipids and clotting process starts.
2) The tissue factor complexes with blood clotting factor VII and activates it.
3) Activated factor VII in presence of ca++ and tissue phospholipids acts on factor –X and activates it. 4) Activated factor X acts on Factor V and activates it.
5) Activated F-X complexes with tissue phospholipids, Factor-V, ca++ And forms a complex called prothrombin activator.
6) Prothrombin activator converts prothrombin in to thrombin under influence of ca++
7) Thrombin acts on fibrinogen and converts it in to fibrin monomers
8) Fibrin monomers polymerize with other fibrin monomers and form long fibrin threads that form reticulum of the clot.
9) At first clot is weak but later on with the help of active fibrin stabilizing factor (F- X III) clot becomes strong.
10)WBCs and RBCs get trapped in to reticulum of the clot
11)Clots adhere to the damaged surface of the blood vessel and thereby prevents the blood loss.
12) Clot retraction Following clot formation, the volume of the clot decreases , this is called as clot retraction platelets are necessary for clot retraction.contain contractile protein Thrombosthenin, which contracts and reduces the volume of the clot. Following this a clear fluid is separated out called as serum.

Extrinsic Pathway of Blood Coagulation Trauma to blood vessel/ Tissue rupture
↓
Tissue Factor and Tissue Phospolipids Tissue Factor(F-III) + Factor VII (Proconvertin) → Activated Factor VII (Proconvertin/Stable Factor)
↙ ca++
Acts on Factor X(Stuart Factor) → Activated Factor X
↙ ca++
Acts on Factor V(Proaccelerin/labile Factor) → Activated Factor V
↙ ca++
Activated Factor X+ Activated Factor V + ca++ + Tissue Phospolipids
↓
Form a complex Prothrombin Activator
↓ ca++
Prothrombin (F-II) → Thrombin
↙ ca++
Fibrinogen(F-I) → Fibrin monomers
↙ ca++
Fibrin monomers → Polymerization

↓
Fibrin stabilizing factor- F-XIII Reticulum + RBC& WBC →clot

Intrinsic Mechanism begins with injury to blood itself and continues through following steps (F-III, F-XII-F-XI-F-IX-FVIII-F-X-F-V)
1) Trauma to blood alters two important clotting factors in the blood Factor XII and Platelet Phospholipids i.e. F- III
2)When F-XII comes in contact with collagen outside the blood vessel,it gets activated and acts as an enzyme for activation of F-XI
3) Damaged platelets adhere to the wet surface of blood vessel and release platelet phospholipids i.e.F- III.

4)Activated factor XII acts enzymatically on F-XI i.e. Plasma Thromboplastin Antecedent (PTA –Factor) and activates it.
5)Activated factor XI acts enzymatically on F- IX i.e. Christmas factor and activates it (ca++ are nessessory)
6) Factor IX activates F-VIII (Anti Haemophilic Factor)
7) activated F- IX , F-VIII and platelet phospholipids,activate factor-X .
8) Activated Factor X acts enzymatically on Factor V (Proaccelarin) and activates it, (ca++ are nessessory).
9) Activated F-V, activated X ,Platelet phospholipids and ca++ form a complex called prothrombin activator Prothrombin activator converts prothrombin in to thrombin under influence of ca++ 10)Thrombin acts on fibrinogen and converts it in to fibrin monomers
11) Fibrin monomers polymerize with other fibrin monomers and form long fibrin threads that form reticulum of the clot.
12)At first clot is weak but later on with the help of active fibrin stabilizing factor (F- X III) clot becomes strong.
13)WBCs and RBCs get trapped in to reticulum of the clot
14)Clots adhere to the damaged surface of the blood vessel and thereby prevents the blood loss.

Intrinsic pathway of clotting mechanism Injury to blood or trauma to blood Blood comes in contact with collagen outside the blood vessel, F-XII get activated and damaged platelets release F-III i.e.platelet phospholipids
F-XII Acts on Factor XI(Plasma Thromboplastin Antecetent) → Activated Factor XI
↙ ca++
F-XI Acts on Factor IX (Christmas Factor) → Activated Factor I X
↙ ca++
F-IXActs on Factor VIII (Anti haemophilic Factor) → Activated Factor VIII
↙ ca++
Activated Factor VIII + Platelet Phospholipids + ca++ → Act on Factor X(Stuart Factor)
↙ ca++
Activated Factor X acts on Factor -V → Activated Factor V(Proaccelerin)
Activated Factor X+ Factor V + Platelet Phospholipids + ca++ Form a complex Prothrombin Activator
↓ ca++
Prothrombin (F-II) → Thrombin
↙ ca++
Fibrinogen(F-I) → Fibrin monomers
↙ ca++
Fibrin monomers → Polymerization
↓ Fibrin stabilizing factor- F-XIII
Reticulum + RBC& WBC →clot

Types of Hearts:

Pulsative heart:

Earth worm heart is a kind of pulsative heart and neurogenic heart.

Tubular heart:

Arthropods [cockroaches] heart is tubular kind of heart.

Two chambered Heart:

The fish heart is much different than the amphibian/reptile/bird/mammal heart. Hearts are very complex--they're not just a bunch of random arteries and veins connecting tissue. Fish hearts simply draw in deoxygenated blood in a single atrium, and pump it out through a ventricle. This system is termed "single circulation", as blood enters the heart, gets pumped through the gills and out to the body, Blood pressure is

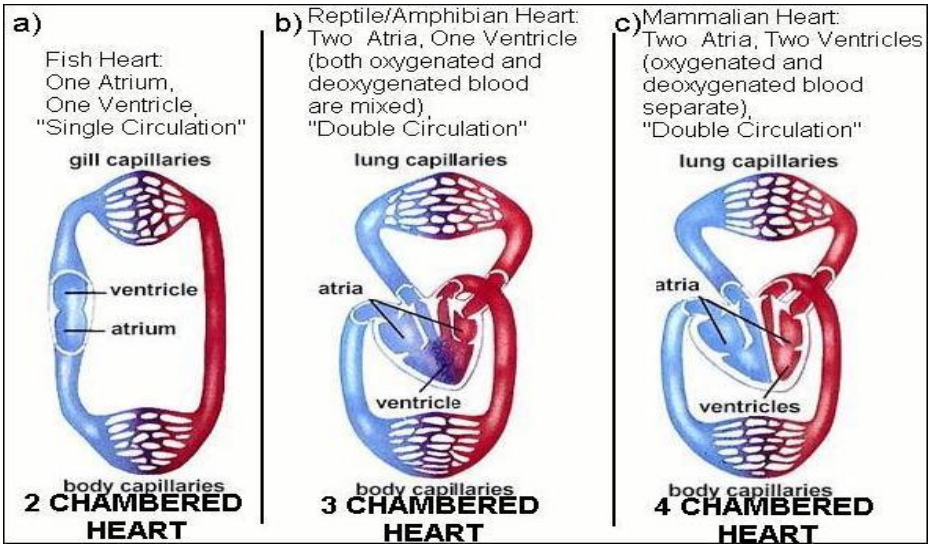
low for oxygenated blood leaving the gills.

Threeandfourchamberedhearts:

3 and 4 chambered hearts have a pulmonary circuit (pathways taking blood from heart to lung and back to heart) that is very complex and must be set up such that blood can travel from the heart to become oxygenated in the lungs and then be properly pumped back the heart and out to the body. The 3 (and 4) chambered heart has "double circulation" (figure 1b and c) and is quite different from "single circulation" offishes.

"Double circulation" has an interior circuit within the heart--blood enters the heart, leaves the heart and gets oxygenated, enters the heart again, and then gets pumped out to the body. Because "Double circulation" allows oxygenated blood to be pumped back into the heart before going out to the body, it pumps blood with much more pressure and much more vigorously than "single circulation".

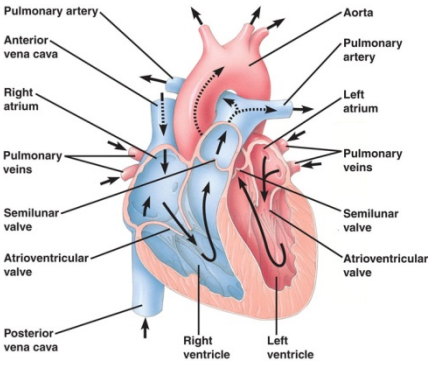
Figure1:



Though the 4 chambered heart has 2 atrium-ventricle pairs, both pairs do not do the same thing. There are 4 steps involved with blood entering the heart: 1) oxygen poor blood enters the first atrium. 2) oxygen poor blood is fed to the first ventricle, which pumps it out to the pulmonary circuit (lungs) where it is enriched in oxygen. 3) Oxygen rich blood just leaving the lungs is pumped back into the second atria. 4) Oxygen rich blood is then fed to the second ventricle, which pumps the oxygen rich blood out of the heart and back into the body for usage.

The 4 chambered heart differs from the 3 chambered heart in that it keeps oxygenated blood completely separate from de-oxygnated blood, because there is one ventricle for deoxgynated blood and one for oxygenated blood. In the 3 chambered heart, a single ventricle pumps both out of the heart, and there is some mixing between fresh and old blood. The 2 ventricle-4 chamber heart prevents mixing allows the blood leaving the heart to have far more oxygen than it would otherwise. This is good for enhancing the more fast paced lifestyle that birds and mammals tend to have, giving an advantage to having a 4 chambered heart.

Structure and Working of Mammalian Heart:



1. The Pericardium

This is a fibrous covering that wraps around the heart and holds it in place. This special membrane also contains a fluid which lubricates the heart in the pericardial space or cavity to prevent friction. The pericardium has two layers, consisting of a visceral layer directly coving the heart and a parietal layer, which forms a sac containing the fluid in the pericardial cavity.

2. The Heart Wall

The wall of the heart is made of three layers:

- **The epicardium,** or the outermost layer of the heart, is a thin layer of membrane that lubricates and protects the outside portion of the heart.
- **The myocardium,** or the muscular layer of the heart wall, consists of the muscle tissue. It consists of the majority of the thickness of the heart and is responsible for the pumping action of the heart.
- **The endocardium,** or the innermost layer that lines the inside of your heart, is a smooth lining that keeps blood from sticking to the heart and prevents the formation of potentially harmful blood clots.

3. Chambers of the Heart

The heart has four chambers:

- Right atrium
- Left atrium
- Right ventricle
- Left ventricle

Atria are smaller than ventricles and have thin, less muscular walls. They are the receiving chambers of the blood, which is delivered to the heart by the large veins. **Ventricles** are the larger, more muscular pumping chambers that push blood out to the circulation. They are connected to large arteries that carry blood to the circulation.

The right atrium and the right ventricle are smaller than the corresponding chambers on the left. They have less muscle in their walls compared to the left side of the heart. The difference in size is related to their functions. Blood from the right side of the heart goes to the pulmonary circulation while blood from the left chambers is pumped to the rest of the body.

4. Blood Vessels

These are tubes which carry blood to different parts of the body:

- **Arteries** deliver oxygen-rich blood from the heart to the rest of the body. The biggest artery is the aorta, which leaves the heart and gives off smaller branches.
- **Veins** deliver deoxygenated blood back to the heart through theinferior and superior vena cava, which drain into the right atrium.
- **Capillaries** are microscopic vessels that connect arteries to veins.

5. Valves

These are fibrous tissue flaps found between the cardiac chambers and within the veins. They serve as gates that ensure one-way flow and prevent the backflow of blood.

- **Atrioventricular valves** are found between each atrium and ventricle. The valve between the right atrium and ventricle is the tricuspid valve, while that found between the left atrium and ventricle is called the mitral valve.
- **Semilunar valves** are found between the ventricles and the large arteries. There is an aortic valve between the left ventricle and the aorta and a pulmonary valve between the right ventricle and the pulmonary artery.

The video below will show you the heart structure and function in a more vivid manner:

Heart Function

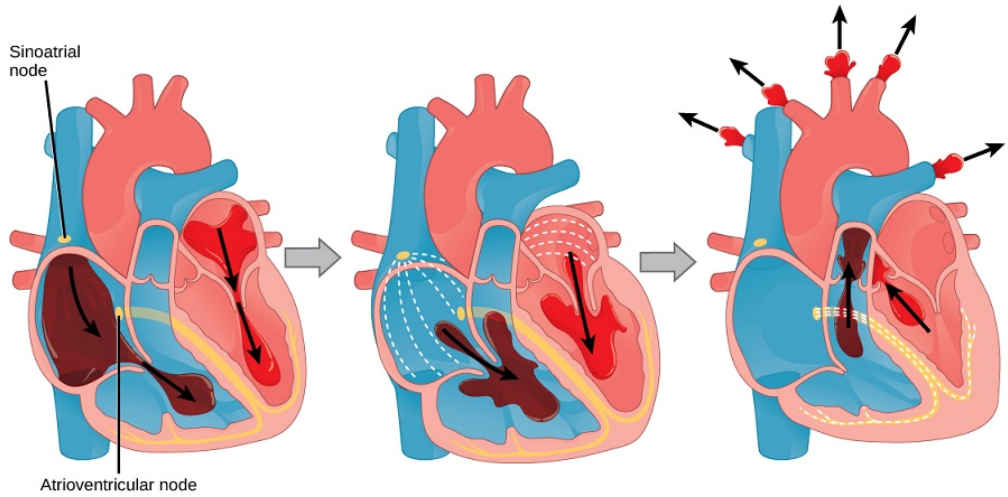
Now, to describe further the complexities ofheart structure and function:

The heart pumps blood to the pulmonary and the systemic circuits.

- **Pulmonary circuit.** Deoxygenated blood from the right ventricle enters the pulmonary artery and goes to the lungs where it receives oxygen and releases carbon dioxide. The oxygenated blood then returns through the pulmonary vein to the left atrium.
- **Systemic circuit.** Oxygenated blood is pumped from the left ventricle to the systemic circulation through the aorta, which branches out into smaller arteries and capillaries to supply the rest of the body with oxygen. From the different organs and tissues, deoxygenated blood returns to the heart through the veins, which drain into the venae cavae, and into right atrium.

Cardiac Cycle

Heart structure and function can also be described by the **Cardiac Cycle**: The heart's main function is to pump blood to the circulation. This is accomplished by a series of contractions (systole) and relaxation (diastole) of the heart muscle, which occurs in a rhythmic or cyclic pattern.



(a) Cardiac diastole: all chambers are relaxed, and blood flows into the heart.

(b) Atrial systole, ventricular diastole: atria contract, pushing blood into the ventricles.

(c) Atrial diastole, ventricular systole: after the atria relax, the ventricles contract, pushing blood out of the heart.

The following sequence describes the cardiac cycle:

Stage 1 - Atrial systole/Ventricular diastole

The right atrium, which has been filled with blood from the circulation, contracts and empties blood into the relaxed right ventricle, with the tricuspid valve open. Almost at the same time, blood from the left atrium, which has come from the lungs, empties into the left ventricle, through the open mitral valve. During this time, the valves in the venae cavae and the pulmonary vein are closed to prevent the backflow of blood.

Stage 2 - Ventricular systole/Atrial diastole

After contraction, the atria relax, the atrioventricular valves close, and the ventricles simultaneously contract with a higher pressure to pump blood into the lungs, via the pulmonary artery, and the systemic circulation, via the aorta.

Stage 3 - Ventricular diastole/atrial systole

After pumping out blood, the ventricles relax and the pulmonary and aortic valves close to prevent backflow. Refilling of the right and left atria occurs as they relax and start the whole cycle once again.

The cardiac cycle produces a heartbeat, which usually takes less than a second. Your heart rate or number of heart beats per minute depends on your level of activity, so you have a slower rate when you are at rest and a faster rate during exercise.

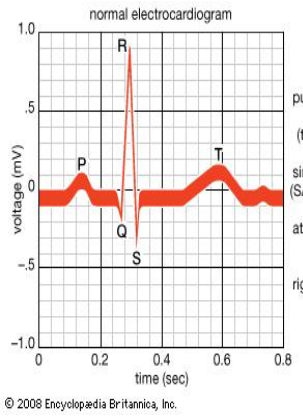
Here are some more information about heart structure and function:

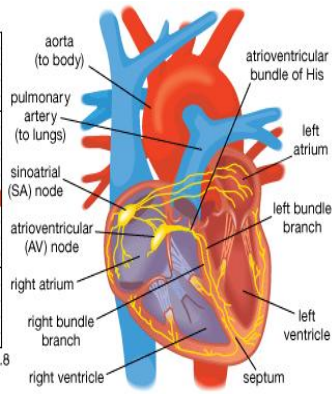
- The human heart is just roughly about the size of a fist.
- Your heart weighs about 10 - 12 ounces (or 280 - 340 grams) if you are a man, and 8 -10 ounces (or 230 - 280 grams) if you are a woman.
- In an adult, the heart beats at an average of 60-80 times per minute.
- The newborn's heart beats faster than an adult heart, at about 70-190 beats/minute.
- Your heart beats at an average of 100,000 times/day or about 3 billion times in your lifetime.
- Your heart pumps about 5-6 liters of blood in your body.

Correlation of ECG Waves with Atrial and Ventricular Systole

As we have seen, the atria and ventricles depolarize and thencontract at different times because the onduction system routescardiac action potentials along a specific pathway. The term **systole** refers to the phase of contraction;the phase of relaxation is **diastole** .The ECG waves predict the timing of atrial and ventricularsystole and diastole. At a heart rate of 75 beats perminute, the timing is as follows

Electrical Activity	Graphic Depiction	Associated Pattern
Atrial Depolarization		P Wave
Delay at AV Node		PR Segment
Ventricular Depolarization		QRS Complex
Ventricular Repolarization		T Wave
No electrical activity		Isoelectric Line





1 A cardiac action potential arises in the SA node. It propagatesthroughout the atrial muscle and down to the AV nodein about 0.03 sec. As the atrial contractile fibers depolarize,the P wave appears in the ECG.

2 After the P wave begins, the atria contract (atrial systole).Conduction of the action potential slows at the AV node because the fibers there have much smaller diameters andfewer gap junctions. (Traffic slows in a similar way where afour-lane highway narrows to one lane in a constructionzone! The resulting 0.1-sec delay gives the atria time to contract, thus adding to the volume of blood in the ventricles, before ventricular systole begins.

3 The action potential propagates rapidly again after enteringthe AV bundle. About 0.2 sec after onset of the P wave, ithas propagated through the bundle branches, Purkinje fibers,and the entire ventricular myocardium.

Depolarization progressesd own the septum, upward from the apex, and outward from the endocardial surface, producing the QRS complex. At the same time, atrial repolarization is occurring, butit is not usually evident in an ECG because the larger QRScomplex masks it.

4 Contraction of ventricular contractile fibers (ventricular systole)begins shortly after the QRS complex appears and continues during the S-T segment. As contraction the apex toward the base of the heart, blood is squeezed upward toward the semi lunar valves.

5 Repolarization of ventricular contractile fibers begins at the apex and spreads throughout the ventricular myocardium. This produces the T wave in the ECG about 0.4 sec after the onset of the P wave.

6 Shortly after the T wave begins, the ventricles start to relax(ventricular diastole). By 0.6 sec, ventricular repolarizationis complete and ventricular contractile fibers are relaxed. During the next 0.2 sec, contractile fibers in both the atria and ventricles are relaxed. At 0.8 sec, the P wave appears again inthe ECG, the atria begin to contract, and the cycle repeats.

BLOOD GROUPS AND BLOOD TYPES

The surfaces of erythrocytes contain a genetically determinedassortment of **antigens** composed of glycoproteins and glycolipids.These antigens, called **agglutinogens** (a-gloo-TIN-o¯-jens), occur in characteristic combinations. Based on the presence orabsence of various antigens, blood is categorized into different **blood groups.** Within a given blood group, there may be two or more different **blood types.** There are at least 24 blood groups and more than 100 antigens that can be detected on the surface
of red blood cells. Here we discuss two major blood groups—ABO and Rh. Other blood groups include the Lewis, Kell, Kidd, and Duffy systems. The incidence of ABO and Rh blood types varies among different population groups, as indicated in Blood plasma usually contains **antibodies** called **agglutinins** (a-GLOO-ti-nins) that react with the A or B antigens if the two are mixed. These are the **anti-A antibody,** which reacts with antigen A, and the **anti-B antibody,** which reacts with antigen
B. The antibodies present in each of the four blood types are shown in. You do not have antibodies that react with the antigens of your own RBCs, but you do have antibodies for any antigens that your RBCs lack. For example, if your blood type is B, you have B antigens on your red blood cells, and you have anti-A antibodies in your blood plasma. Although agglutinins start to appear in the blood within a few months after birth, the reason for their presence is not clear. Perhaps they are formed in response to bacteria that normally inhabit the gastrointestinal tract. Because the antibodies are large IgM-type antibodies that do not cross the placenta, ABO compatibility between a mother and her fetus rarely causes problems.

Transfusions

Despite the differences in RBC antigens reflected in the bloodgroup systems, blood is the most easily shared of human tissues, saving many thousands of lives every year through transfusions. A **transfusion** is the transfer of whole blood or blood components (red blood cells only or blood plasma only) into the bloodstream or directly into the red bone marrow. A transfusion is most often given to alleviate anemia, to increase blood volume (for example, after a severe hemorrhage), or to improve immunity. However, the normal components of one person's RBC plasma membrane can trigger damaging antigen– antibody responses in a transfusion recipient. In an incompatible blood transfusion, antibodies in the recipient's plasma bind to the antigens on the donated RBCs, which causes **agglutination** , or clumping, of the RBCs. Agglutination is an antigen–antibody response in which RBCs become cross linked to one another. (Note that agglutination is not the same as blood clotting.) When these antigen–antibody complexes form, they activate plasma proteins of the complement family. In essence, complement molecules make the plasma membrane of the donated RBCs leaky, causing **hemolysis** (rupture) of the RBCs and the release of hemoglobin into the blood plasma. The liberated hemoglobin may cause kidney damage by clogging the filtration membranes. Although quite rare, it is possible for the viruses that cause AIDS and hepatitis B and C to be transmitted through transfusion of contaminated blood products. Consider what happens if a person with type A blood receives a transfusion of type B blood. The recipient's blood (type A) contains A antigens on the red blood cells and anti-B antibodies in the plasma. The donor's blood (type B) contains B antigens and anti-A antibodies. In this situation, two things can happen. First, the anti-B antibodies in the recipient's plasma can bind to the B antigens on the donor's erythrocytes, causing

agglutination and hemolysis of the red blood cells. Second, the anti-A antibodies in the donor's plasma can bind to the A antigens.