

**Physiology:** is the science of the *function* of living systems. This includes how organisms, organ systems, organs, cells and bio-molecules carry out the chemical or physical functions that exist in a living system.

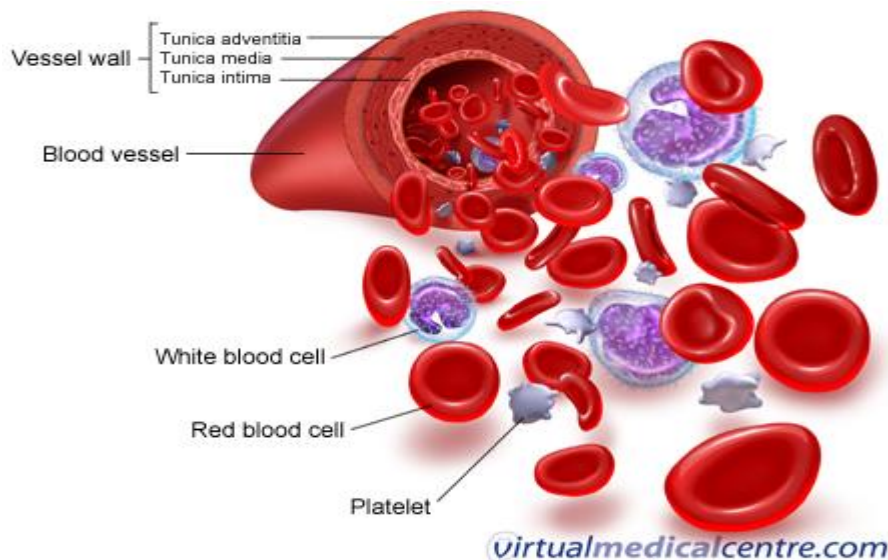
## Circulatory system (Hematology)

Hematology (American English) or haematology (British English) is the branch of biology (physiology), hematology is defined as the study of the blood, and the term (hemo or hemato) is derived from the Greek word for blood.

### **The human blood:**

Blood is one of the most important and unusual connective tissues with a liquid matrix in the animal body.

If the whole blood treated to prevent clotting, is left standing in a test tube, the formed elements will settle down to the bottom, leaving the fluid plasma above.



### **Blood volume:**

An adult human has about 5 to 6 liters of blood, which is roughly 7 to 8 percent of total body weight. Infants and children have comparably lower volumes of blood, roughly proportionate to their smaller size.

### **Composition of blood**

The intracellular liquid matrix of blood is called plasma. There are three formed element in the plasma which are:

- 1-Red blood cells (erythrocytes)
- 2-White blood cells (leukocytes)
- 3-Platelets (thrombocyte).

The % of formed elements is 40-50 %; The % of plasma is 50-60 % in whole blood.

**The plasma:** is the liquid part of the blood, yellow or colorless. It is about 55-70 % of the whole blood. It is consist of:

- 1-Water (91%).
- 2-Gases(O<sub>2</sub>, CO<sub>2</sub>,N)
- 3-Proteins (Albumin, Globulin, Fibrinogen).
- 4-Glucose, lactate , pyruvate .
- 5-Lipids (Fat, Lecithin, cholesterol).
- 6-Non proteinous nitrogenic product such as (Amino acids, Urea, Uric acid, keratin, ammonium salt).
- 7-Inorganic substances (Na, K, Ca, Mg, Cl-,S,P,Fe,Mn,Co,Cu,Zn,I<sub>2</sub> ).
- 8-Enzymes . 9- Hormones . 10- Vitamins . 11- Pigments .

The division between albumin & globulin is based on molecular weight.

**Function of plasma:** The plasma contain number of proteins which play important role in following functions :

- 1-Plasma protein is in balance with tissues protein. It protein store.
- 2-Keep osmotic pressure of blood by re-transport of body fluid which escape from blood to tissues.
- 3-Keep blood pressure constant by keeping normal viscosity .
- 4-Affect on the suspension stability of RBC in blood & prevent its sedimentation.
- 5-Help in regulation of blood PH(7.4).
- 6-Provide the body with antibodies .
- 7-Play role in hormone & drug transport.
- 8-Play role in transport of minerals & vitamins .

**Blood serum :** is liquid residue of blood after clotting, it is plasma with no fibrinogen and clotting factor 11 , V, VI11. And it contains serotonin.

## Cellular component of blood:

### 1- Red blood cells (95%):

Red blood cells make up almost 45 percent of the blood volume. Its non motile cells, with no nucleus, mitochondria, Golgi bodies, centrioles & RNA (Ribonucleic acid). It is circular disc, changes its shape in capillaries.

Number of RBC changed according to these factors:

Age ,sex, exercise , feeding state , lactation, pregnancy haemodilution , estrous cycle , surrounding temperature , altitude , ecological factors .

Their primary function is to carry oxygen from the lungs to every cell in the body. RBCs are composed predominantly of a protein and iron compound, called hemoglobin that captures oxygen molecules as the blood moves through the lungs, giving blood its red color.



## 2- White blood cells:

Less than RBC in number, with no pigment, it contain nucleus and other cell organelles. The number of WBC changed daily and with feeding and stress. White blood cells only make up about 3 % of blood cells, but their small number belies their immense importance. They play a vital role in the body's immune system—the primary defense mechanism against invading bacteria, viruses, fungi, and parasites. Total number in human: is' about 8000 cell /cm<sup>3</sup> blood.

**WBC Classified into two main groups: \*Granulocytes(Polymorphonuclear granulocytes):**

Contain granules in the cytoplasm and nucleus more than one lobes, which subdivided into three types according to the granules staining:

1-Neutrophils. 2-Acidophils. 3-Basophils.

**\*Agranulocyte:** no granules in the cytoplasm and nucleus of one lobe, divided into two types :

1-Lymphocyte. 2-Monocyte.

Granulocytes:

**-Neutrophils:**

- 1-Form about 65% of total WBC, and it is motile cells.
- 2-Granules stained with neutral stain, which have light colour.
- 3-Nucleus consist from more than one lobes (3-5 lobe).
- 4-Women may show drum stick .

Function:

Neutrophil act as phagocytic cells , its function is defense against microbes , and it formed in bone marrow.

**-Acidophil (Eosinophils):**

- 1-Its percentage is 4% .
- 2-Nucleus bilobed.
- 3-Cytoplasm contain acidophilic granules .
- 4-Formed in bone marrow.

Its function is related to allergic conditions & some parasitic cases.

**-Basophil:**

- 1- Its percentage is 1% .
- 2- Nucleus longitude as S shape .

3-Cytoplasm contain basophilic blue granules.

4-Formed in bone marrow. In the tissues, they are called mast cells.

Its function is formation of heparin & histamine.

### Agrnulocvtes ∴ **lymphocyte** ;

1-its percentage is 25%.

2-Nucleus is large .

3-Cytoplasm with no granules & as a thin layer a round the nucleus .

4-Formed in lymphatic tissues (lymph node, spleen, tonsils, thymus gland).

Its function is formation of antibodies

### **monocyte:**

1-Its percentage is 5%.

2-Large cells .

3-Nucleus large and take one side in the cell & the cytoplasm in other side




4-Formed in spleen & bone marrow.

Its function : phagocytosis of microbes

### **3- Thrombocytes (platelets):**





Thrombocytes, or platelets, are not complete cells, but are small fragments of very large cells called megakaryocytes. Megakaryocytes develop from hemocytoblasts in the red bone marrow. Thrombocytes become sticky and clump together to form platelet plugs that close breaks and tears in blood vessels. They also initiate the formation of blood clots.

#### Formed Elements of the Blood

Cell type	Illustration	Description*	Number of cells/mm <sup>3</sup> (μl) of blood	Duration of development (D) and life span (LS)	Function
<b>Erythrocytes</b> (red blood cells, RBCs)		Biconcave, anucleate disc; salmon-colored; diameter 7–8 μm	4–6 million	D: 5–7 days LS: 100–120 days	Transport oxygen and carbon dioxide
<b>Leukocytes</b> (white blood cells, WBCs)		Spherical, nucleated cells	4,800–10,800		
Granulocytes		Nucleus multilobed; inconspicuous cytoplasmic granules; diameter 10–14 μm	3000–7000	D: 6–9 days LS: 6 hours to a few days	Phagocytize bacteria
▪ Neutrophil					
▪ Eosinophil		Nucleus bilobed; red cytoplasmic granules; diameter 10–14 μm	100–400	D: 6–9 days LS: 8–12 days	Kill parasitic worms; destroy antigen-antibody complexes; inactivate some inflammatory chemicals of allergy

\*Appearance when stained with Wright's stain.

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<b>Leukocytes</b> (white blood cells, WBCs)		Spherical, nucleated cells	4,800–10,800		
<ul style="list-style-type: none"> <li>▪ Basophil</li> </ul>		Nucleus lobed; large blue-purple cytoplasmic granules; diameter 10–12 μm	20–50	D: 3–7 days LS: ? (a few hours to a few days)	Release histamine and other mediators of inflammation; contain heparin, an anticoagulant
Agranulocytes		Nucleus spherical or indented; pale blue cytoplasm; diameter 5–17 μm	1500–3000	D: days to weeks LS: hours to years	Mount immune response by direct cell attack or via antibodies
<ul style="list-style-type: none"> <li>▪ Lymphocyte</li> <li>▪ Monocyte</li> </ul>					
		Nucleus U or kidney shaped; gray-blue cytoplasm; diameter 14–24 μm	100–700	D: 2–3 days LS: months	Phagocytosis; develop into macrophages in
<b>Platelets</b>		Discoid cytoplasmic fragments containing granules; stain deep purple; diameter 2–4 μm	250,000–500,000	D: 4–5 days LS: 5–10 days	Seal small tears in blood vessels; instrumental in blood clotting

\*Appearance when stained with Wright's stain.

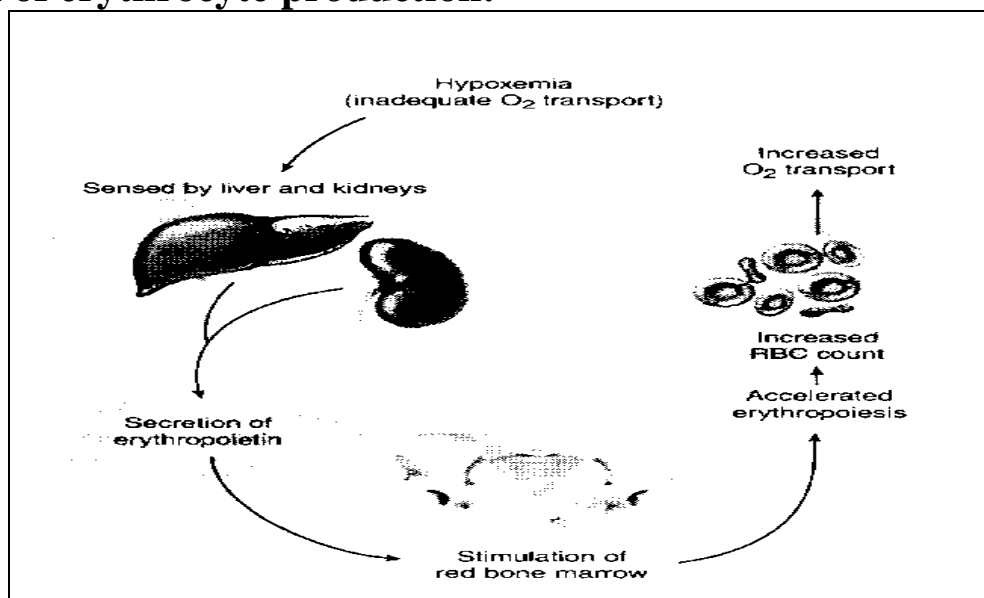
## Hematopoiesis

The process of blood cell production, called hematopoiesis or hemopoiesis, occurs in the embryo and fetus in tissues such as the yolk sac, liver, thymus, spleen, lymph nodes, and red bone marrow. After birth, hematopoiesis is confined primarily to red bone marrow, with some lymphoid tissue helping in the production of lymphocytes. In young children nearly all bone marrow produces blood cells. However, in adults hematopoietic red marrow confined to the skull, ribs, sternum, vertebrae, pelvis, proximal femur, and proximal humerus.

### Erythrocyte Production

Erythrocyte production is called **erythropoiesis**. It normally generates about 2.5 million RBCs per second (20 ml/day). The proerythroblast is the first committed cell, having receptors for the hormone erythropoietin (EPO). Once EPO receptors are in place, the cell is committed exclusively to producing RBCs. EPO is secreted by the kidneys and liver and stimulates proerythroblasts to differentiate into erythroblasts.

### Regulation of erythrocyte production:



**A negative feedback loop for correcting hypoxemia**

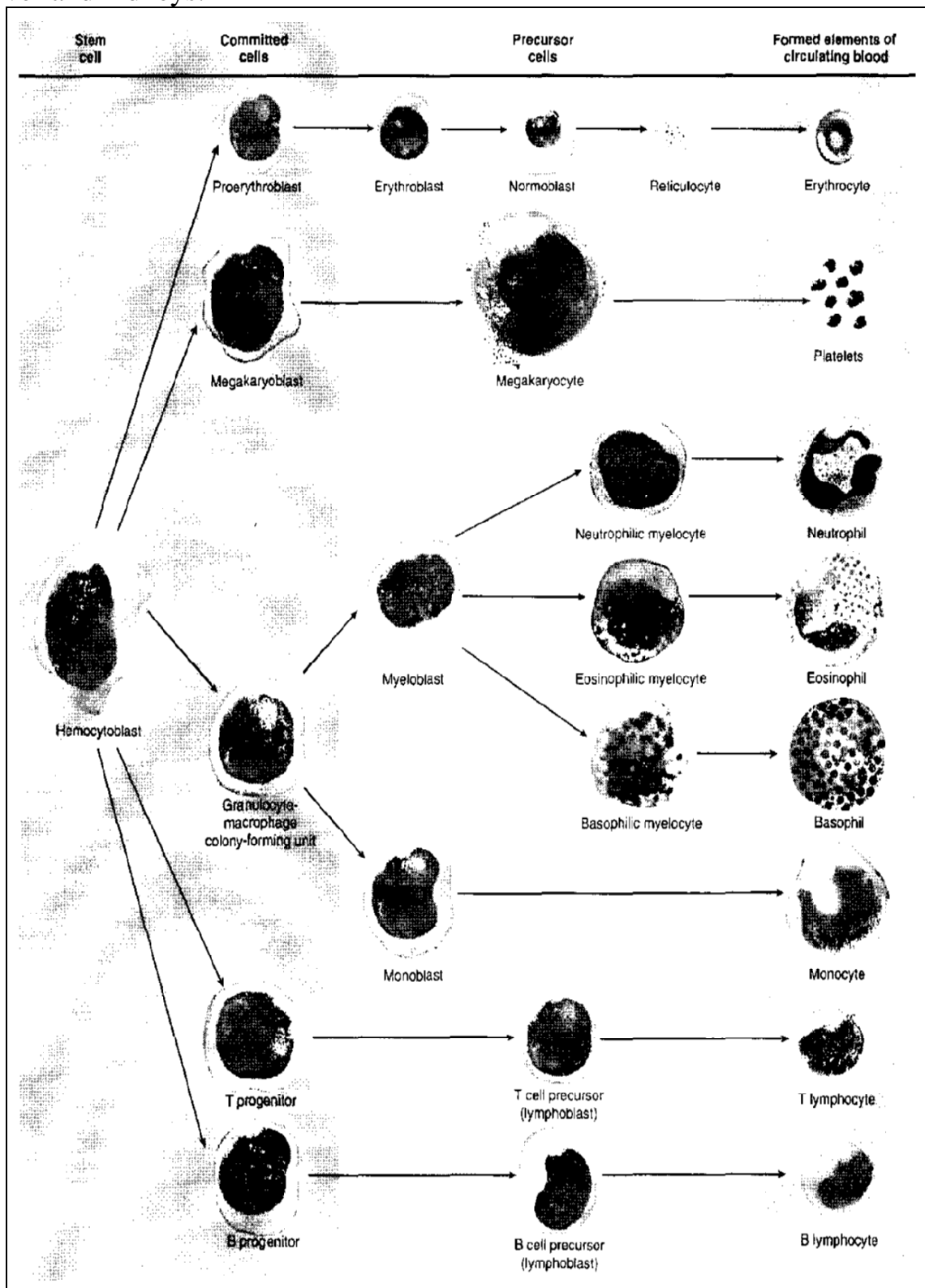
### Leukocyte Production

Leukopoiesis is the production of white blood cells. It begins when some hemocytoblasts differentiate into three types of committed cells:

1. B progenitors, destined to become B lymphocytes;
2. T progenitors, which become T lymphocytes; and
3. Granulocyte-macrophage colony-forming units, which become granulocytes and monocytes. These committed cells have receptors for colony-stimulating factors (CSFs).

### Platelet Production

The production of platelets is called thrombopoiesis because platelets used to be called thrombocytes. Thrombopoiesis begins when a hemocytoblast develops receptors for the hormone thrombopoietin, which, like erythropoietin, is produced by the liver and kidneys.

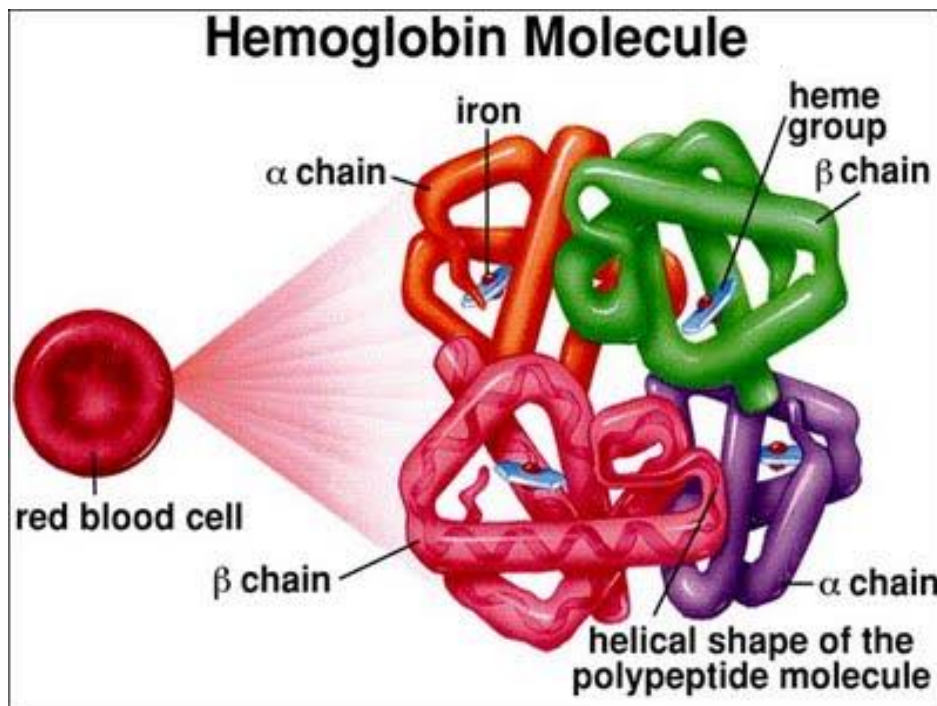


**The stages of hematopoiesis or production of the formed elements of blood**

## Hemoglobin

### Structure:

Each erythrocyte contains about 280 million molecules of hemoglobin. Hemoglobin consists of four protein chains called **globins**(glycoprotein). Two of these, the *alpha* ( $\alpha$ ) *chains*, are 141 amino acids long, and the other two, the *beta* ( $\beta$ ) *chains*, are 146 amino acids long. Each chain is conjugated with a non protein moiety called the **heme** group, which binds oxygen to a ferrous ion ( $\text{Fe}^{+2}$ ) at its center. A heme group is a flat ring molecule containing carbon, nitrogen and hydrogen atoms, with a single  $\text{Fe}^{2+}$  ion at the center. Without the iron, the ring is called a porphyrin.



**Hb value :** Normal ranges of Hb ( g / 100 ml ) are :

Men  $15.5 \pm 2.5$  g/100 ml blood.

Women  $14 \pm 2.5$  g/100 ml blood.

Infant  $16.5 \pm 3$  g/100 ml blood.

Children 3 month  $11.5 \pm 2$

Children 1 year  $12 \pm 1.5$

Children 3- 6 year  $13 \pm 1$

Children 10 -12 year  $13 \pm 1.5$

**Function:** transport of respiratory gases  $\text{O}_2$  and  $\text{CO}_2$  . It carries  $\text{O}_2$  from lung to tissues and  $\text{CO}_2$  from tissues to the lung .

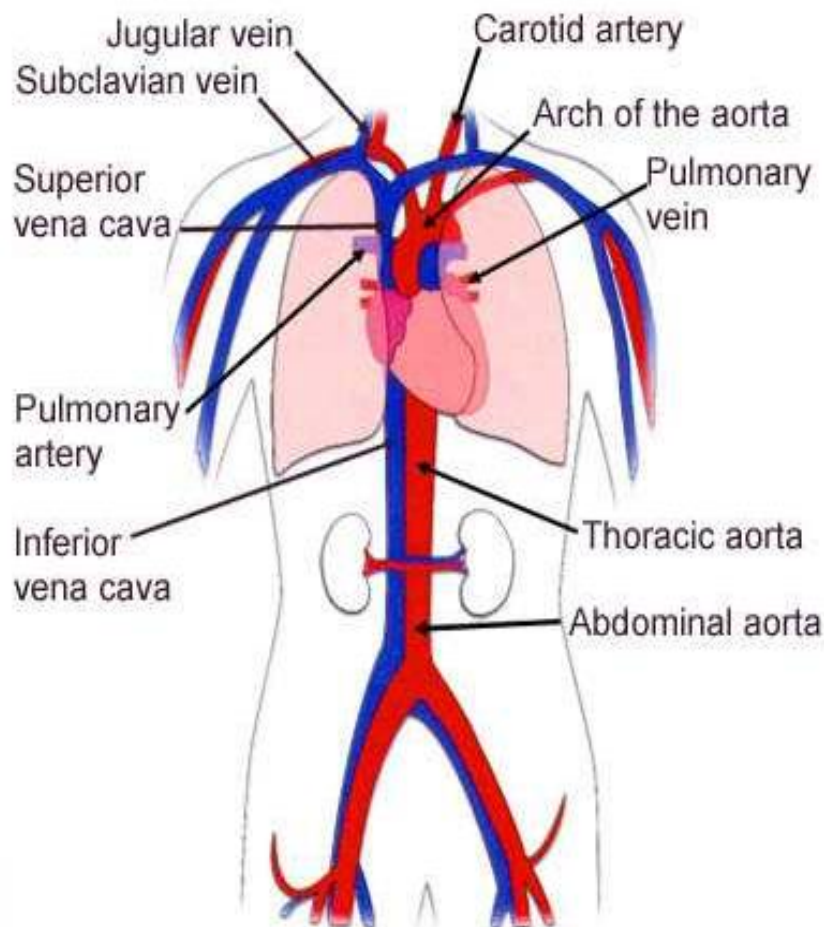
\*A value less than  $<13$  gm in male or less than  $<11.5$  gm in female is called **Anemia**; but a value more than  $>18$  gm in male or more than  $16.5$  gm in female is called **polycythaemia** .

Formation of plasma proteins :

The plasma albumin, alpha( $\alpha$ ), beta( $\beta$ ) globulin & the blood clotting factors ( prothrombin & fibrinogen ) are formed in the liver .the gamma ( $\gamma$ )globulin is formed by cells of the reticulo-endothelial system & their derivatives , such as plasma cells & lymphocytes .When the liver is diseased lead to decrease the level of albumin & increase the level of globulin in plasma .

**The Cardiovascular System**

The circulatory system consist of 2 pump and 2 sets of tubes. The 2 pumps are the right and left sides of the heart. The 2 sets of tube are the systemic and pulmonary circulation. The right side transfer blood from great veins to pulmonary artery. The left side transfer blood from pulmonary veins to aorta .

**The heart;**

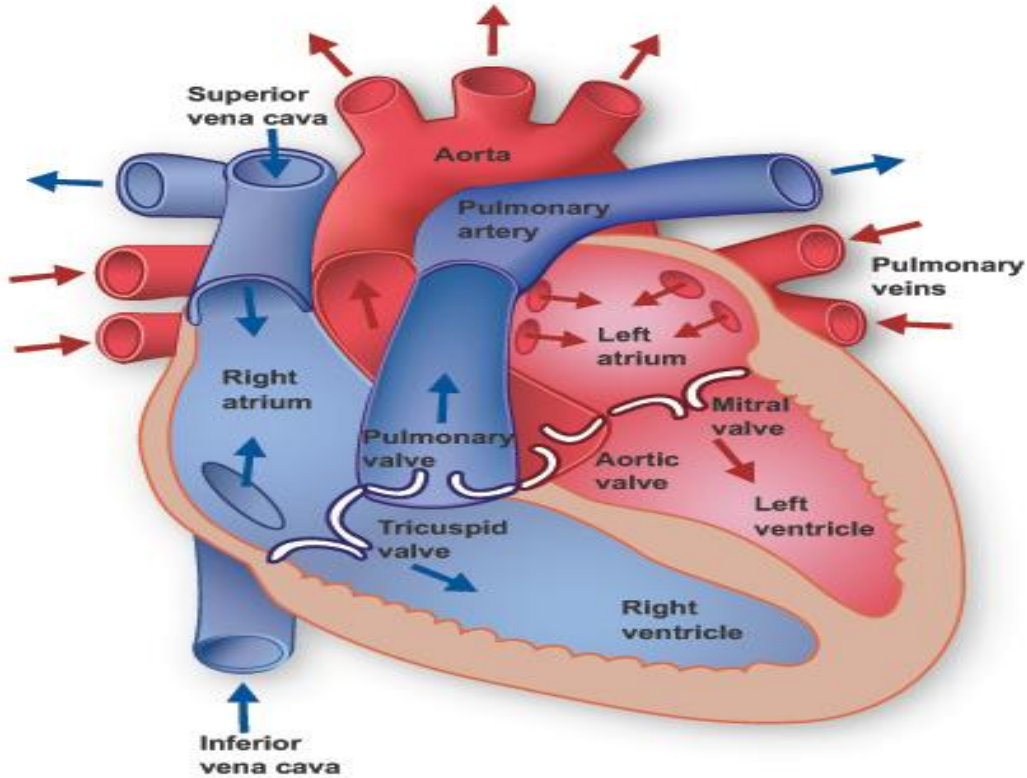
The heart is the principle pump which circulates blood around body each side of the heart consist of 2 chambers (atrium & ventricle)

Heart valves:

In heart valves exist between the atria and ventricles and between ventricle and aorta and between ventricle and pulmonary artery these valves are :

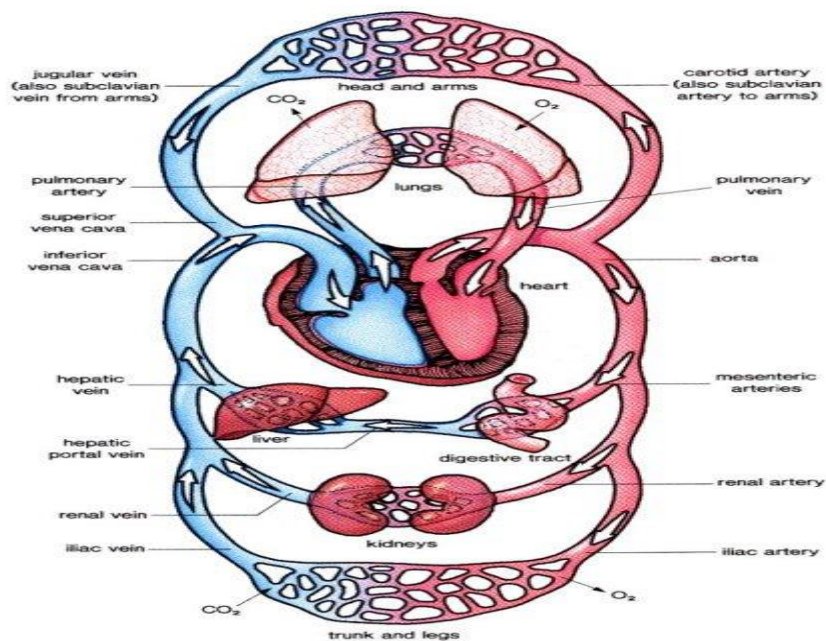
- 1- Atrioventricular valves : Are valves between atria and ventricle of each heart side. It prevent passage of blood from ventricle to atrium during

ventricle contraction, in the left side has mitral valve and the right side has tricuspid.  
 2- Semilunar valves. Prevent passage of blood from aorta and pulmonary artery to ventricles during ventricle relaxation . Are of two type:  
 A-Aortic valve : between left ventricle and aorta.  
 B-Pulmonary valve: between right ventricle and pulmonary artery.



Cardiac cycle -The heart act as a pump, which produces sequence of events during single heart beat. Are of 4 stages

- 1-Late diastole      2-Atrial systole
- 3-Ventricle systole   4-Ventricle diastole



Heart beats (spread of impulse):

Heart beat originate from area called *pacemaker* at sinoatrial node (SA) node then passed to atria and then to *atrioventricular* node (AV) node and then to bundle of *His* after that to its branches called *purkinje* fibers on ventricle wall.

Cardiac out put:

The volume of blood pumped by each ventricle are in minute. The volume of blood pumped by from each ventricle with each systole is called *stroke volume*.

Cardiac out put = stroke volume x Rate of heart beat.

Heart sound :

Heart sounds produced as a result of closing heart valves to prevent blood flow in reverse direction.

First heart sound . it like (LUP) occur as a result of closing of atrioventricular valve at early ventricular systole .

Second heart sound : It like (DUP) occur as a result of closing of semilunar valves .

Third heart sound : caused by blood rushing into ventricle during diastole

Forth heart sound : some time audible , caused by atrium contraction .

Electrocardiograph (ECG):

Is record of electrical changes occur during each heart beat as a result of depolarization in systole and repolarization in diastole.

The electrical changes of heart muscle transfer through body fluid in to the body surface, and then could be recorded by ECG apparatus through special leads.

The electrocardiogram is:

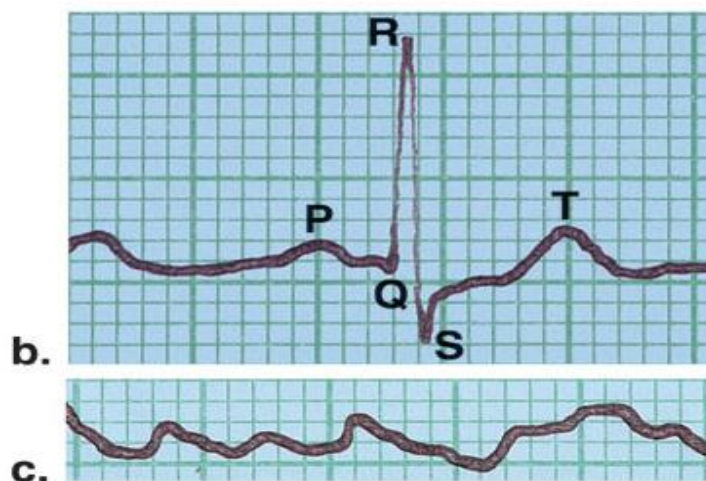
P-wave: Represents arterial depolarization, which results in arterial contraction.

P-Q - interval with no deflection.

QRS - ventricle excitation.

T- wave : end of the excitation .

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**Blood pressure(B.P.):**

The pressure produced by the contraction of left ventricle on blood in the artery is called arterial blood pressure or blood pressure . It fluctuate from (120 - 80 mm. Hg) above atmospheric pressure. The pressure on the blood in large veins and right atrium is equal to atmospheric pressure (0 mm. Hg) and called venous blood pressure.

Measurement of blood pressure :

B.P. of human measured in brachial artery by sphygmomanometer . by B.P. measuring 2 values obtained :

- 1-systolic pressure : represent blood pressure during systole .
- 2-diastolic pressure : represent b.p. during diastole .

Regulation of b.p. :

The regulation of blood pressure depend on 2 factors are:

- 1 -cardiac out put.
- 2-peripheral resistance from blood vessels .

Cardiac out put:

This depend on stroke volume and heart beats rate ,which in turn changed by nerve and hormone control.

peripheral resistance :

It is the resistance of circulation system that lies mainly in arterioles . it depend on 2 factors :

- 1-cross - sectional area of blood vessels .
- 2-viscosity of blood .

**Variations in B.p. levels :**

There are many factors caused either increasing or decreasing normal level of b.p. . these factors are :

- 1-sex : b.p. in male higher than in female .
- 2-age : b.p. : increase with aging .
- 3-Body weight: b.p. : higher in obesity .
- 4-development: b.p. : increase after birth .
- 5-body posture :
- 6-muscular activity :
- 7-excitement or emotion
- 8-alcohol and adrenaline increase b.p.
- 9-Bleeding and anesthesia & surgical shock decrease B.p.