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Cardiovascular system

Cardiovascular system(C.V.S.)(Circulatory System) or (Circulation)

Cardiovascular system (C.V.S.) :- Is the system responsible on the transportation of different food material, oxygen and hormones to every cells in the body and then .It will be carry the waste material from the site of production to the of excretion.

-This system include the heart and blood vessels:-

The Heart

Heart which is a pump the blood to all part of body. Two kinds of heart will be present in animals kingdom.

1-**Neurogenic Heart**:- which present in most types of fish, insect and this kind of heart, the beat will originate from nervous tissue and it need a nerve, to transport the heart beat, this mean that if we isolated the myogenic heart from body, the heart will continue beating.

2-**Myogenic Heart**:- This types it present in mammals and most other animals, in this kinds of heart, heart beat will originate from cardiac muscle itself and does not need any nervous stimulation occur.

Anatomy of the heart:-

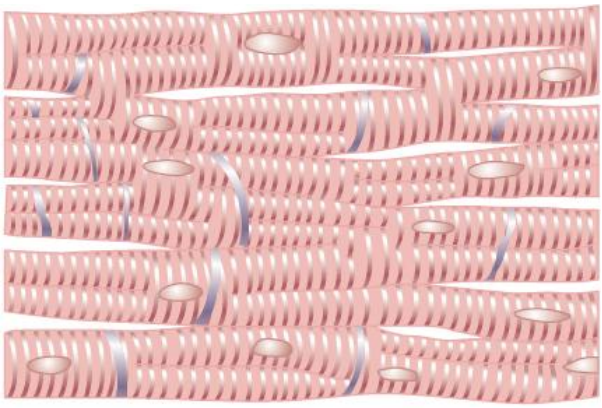
The heart is a muscular organ enclosed in a fibrous sac, the **pericardium,** and located in the chest (thorax). The extremely narrow space between the pericardium and the heart is filled with a watery fluid that serves as a lubricant as the heart moves within the sac. The walls of the heart are composed primarily of cardiac muscle cells and are termed the **myocardium.** The inner surface of the walls—that is, the surface in contact with the blood within the cardiac chambers is lined by a thin layer of cells known as **endothelial cells,** or **endothelium.**

Typical histological picture of cardiac muscle, demonstrating cardiac muscle fibers arranged in a latticework, with the fibers dividing, recombining, and then spreading again. One also notes immediately from this figure that cardiac muscle is *striated* in the same manner as in typical skeletal muscle. Further, cardiac muscle has typical myofibrils that contain *actin* and *myosin filaments* almost identical to those found in skeletal muscle; these filaments lie side by side and slide along one another during contraction in the same manner as occurs in skeletal muscle. But in other ways, cardiac muscle is quite different from skeletal muscle, as we shall see.

Cardiac Muscle as a Syncytium:-

The dark areas crossing the cardiac muscle fibers are called *intercalated discs;* they are actually cell membranes that separate individual cardiac muscle cells from one another. That is, cardiac muscle fibers are made up of many individual cells connected in series and in parallel with one another. At each intercalated disc the cell membranes fuse with one

another in such a way that they form permeable "communicating" junctions (gap junctions) that allow almost totally free diffusion of ions. Therefore, from a functional point of view, ions move with ease in the intracellular fluid along the longitudinal axes of the cardiac muscle fibers, so that action potentials travel easily from one cardiac muscle cell to the next, past the intercalated discs. Thus, cardiac muscle is a *syncytium* of many heart muscle cells in which the cardiac cells are so interconnected that when one of these cells becomes excited, the action potential spreads to all of them, spreading from cell to cell throughout the lattice work interconnections.



As noted earlier, the a heart is divided into a ventricle. Located between the atrium and ventricle in each half of the heart are the **atrioventricular (AV) valves,** which permit blood to flow from atrium to ventricle but not from ventricle to atrium.

The right AV valve is called the **tricuspid valve,** and The opening and closing of the AV valves is a passive process resulting from pressure differences across the valves. When the blood pressure in an atrium is greater than that in the ventricle separated from it by a valve, the valve is pushed open and flow proceeds from atrium to ventricle. In contrast, when a contracting ventricle achieves an internal pressure greater than that in its connected atrium, the AV valve between them is forced closed. Therefore, blood does not normally move back into the atria but is forced into the pulmonary trunk from the right ventricle and into the aorta from the left ventricle. To prevent the AV valves from being pushed up into the atrium, the valves are fastened to muscular projections **(papillary muscles)** of the ventricular walls by fibrous strands (**chordae tendinae**). The papillary muscles do *not* open or close the valves. They act only to limit the valves' movements and prevent them from being everted. The opening of the right ventricle into the pulmonary trunk and of the left ventricle into the aorta also contain valves, the **pulmonary** and **aortic valves ,**respectively (these valves are also collectively referred to as the semilunar valves). These valves permit blood to flow into the arteries

during ventricular contraction but prevent blood from moving in the opposite direction during ventricular relaxation. Like the AV valves, they act in a purely passive manner. Their being open or closed depends upon the pressure differences across them.

Another important point concerning the heart valves is that, when open, they offer very little resistance to flow. Accordingly, very small pressure differences across them suffice to produce large flows. In disease states, however, a valve may become narrowed so that even when open it offers a high resistance to flow. In such a state, the contracting cardiac chamber must produce an unusually high pressure to cause flow across the valve.

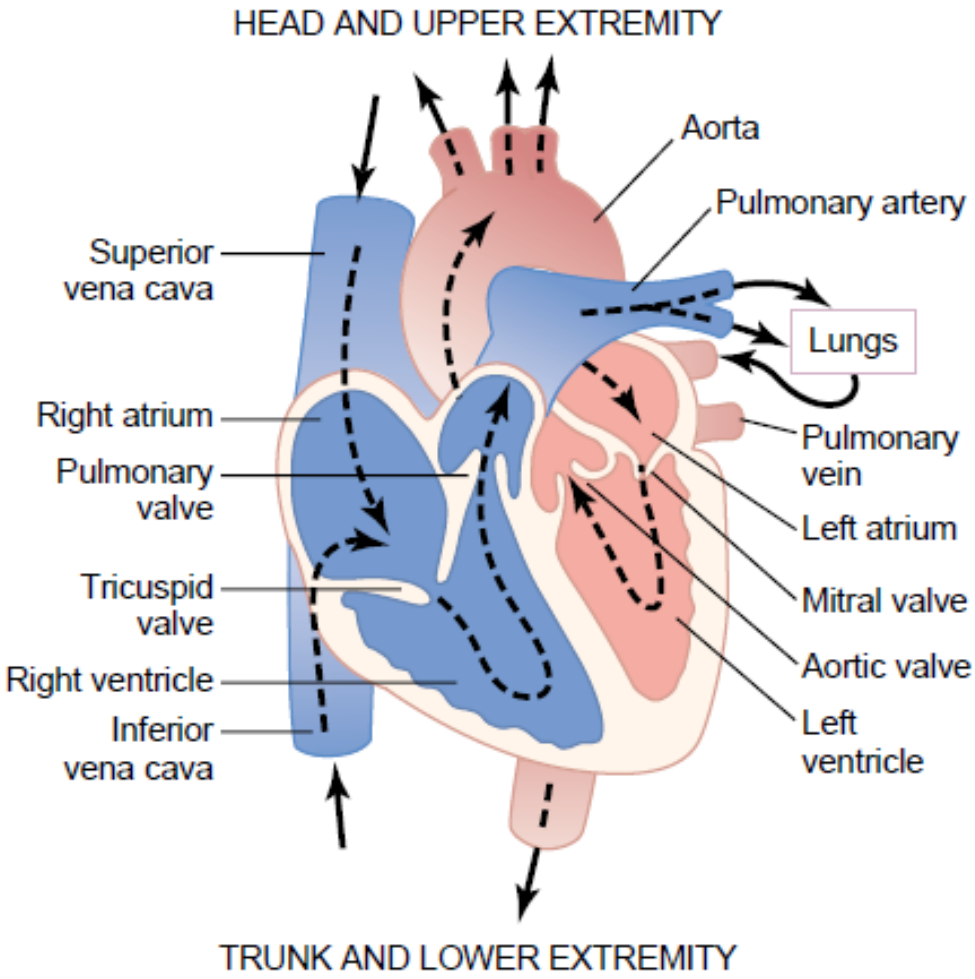
There are no valves at the entrances of the superior and inferior venae cavae (plural of vena cava) into the right atrium, and of the pulmonary veins into the left atrium. However, atrial contraction pumps very little blood back into the veins because atrial contraction compresses the veins at their sites of entry into the atria, greatly increasing the resistance to backflow. (Actually, a little blood is ejected back into the veins, and this accounts for the venous pulse that can often be seen in the neck veins when the atria are contracting).

Approximately 1percent of the cardiac-muscle cells do not function in contraction, but have specialized features that are essential for normal heart excitation. These cells constitute a network known as the **conducting system** of the heart and are in contact with the other cardiac-muscle cells via gap junctions. The conducting system initiates the heartbeat and helps spread the impulse rapidly throughout the heart. One final point about the cardiac-muscle cells is that certain cells in the atria secrete the family of peptide hormones collectively called atrial natriuretic factor.

Innervation:- the heart receives a rich supply of sympathetic and parasympathetic nerve fibers, the latter contained in the vagus nerves. The sympathetic postganglionic fibers release primarily norepinephrine, and the parasympathetics release primarily acetylcholine. The receptors for norepinephrine on cardiac muscle are mainly beta-adrenergic. The hormone epinephrine, from the adrenal medulla, combines with the same receptors as norepinephrine and exerts the same actions on the heart. The receptors for acetylcholine are of the muscarinic type.

Blood Supply:- The blood being pumped through the heart chambers does not exchange nutrients and metabolic end products with the myocardial cells. They, like the cells of all other organs, receive their blood supply via arteries that branch from the aorta. The arteries supplying the myocardium are the **coronary arteries,** and the blood flowing through them is termed the **coronary blood flow.** The coronary

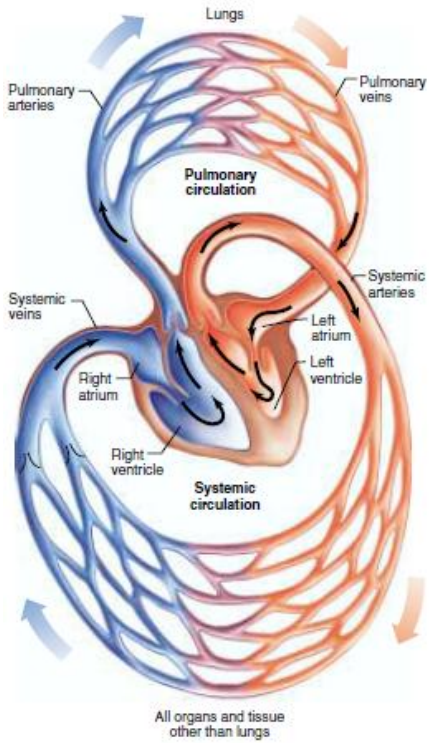
arteries exit from the very first part of the aorta and lead to a branching network of small arteries, arterioles, capillaries, venules, and veins similar to those in other organs. Most of the coronary veins drain into a single large vein, the coronary sinus, which empties into the right atrium.

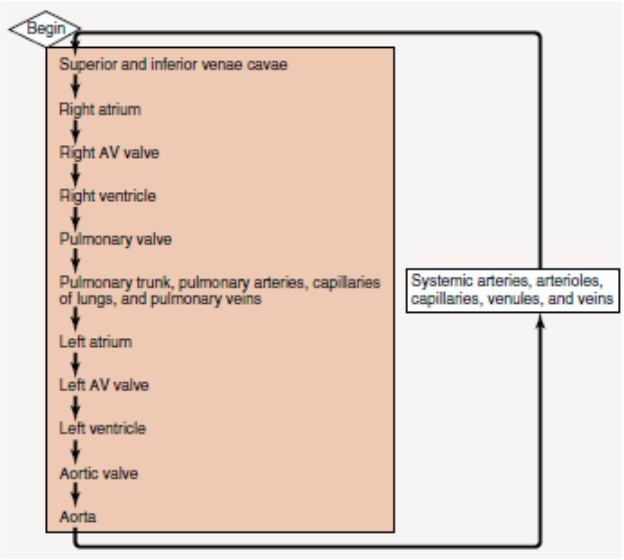


The rapid flow of blood throughout the body is produced by pressures created by the pumping action of the heart. This type of flow is known as **bulk flow** because all constituents of the blood move in one direction together. The extraordinary degree of branching of blood vessels ensures that almost all cells in the body are within a few cell diameters of at least one of the smallest branches, the capillaries. Nutrients and metabolic end products move between capillary blood and the interstitial fluid by diffusion. Movements between the interstitial fluid and cell interior are accomplished by both diffusion and mediated transport. At any given moment, approximately 5 percent of the total circulating blood is actually in the capillaries. Yet it is this 5 percent that is performing the ultimate functions of the entire cardiovascular system: the supplying of nutrients and the removal of metabolic end products. All other components of the system subserve the overall aim of getting adequate blood flow through

the capillaries. This point should be kept in mind as we describe these components. As discovered by the British physiologist William Harvey in 1628, the cardiovascular system forms a circle, so that blood pumped out of the heart through one set of vessels returns to the heart via a different set. There are actually two circuits both originating and terminating in the heart, which is divided longitudinally into two functional halves. Each half contains two chambers: an upper chamber—the **atrium**—and a lower chamber—the **ventricle.** The atrium on each side empties into the ventricle on that side, but there is no direct communication between the two atria or the two ventricles in the adult heart. Blood is pumped via one circuit, the **pulmonary circulation,** from the right ventricle through the lungs and then to the left atrium. It is then pumped through the **systemic circulation** from the left ventricle through all the organs and tissues of the body except the lungs and then to the right atrium. In both circuits, the vessels carrying blood *away from the heart* are called **arteries,** and those carrying blood from either the lungs or all other parts of the body (peripheral organs and tissues) back *toward the heart* are called **veins**.

In the systemic circuit, blood leaves the left ventricle via a single large artery, the **aorta**. The arteries of the systemic circulation branch off the aorta, dividing into progressively smaller vessels. The smallest arteries branch into **arterioles,** which branch into a huge number (estimated at 10 billion) of very small vessels, the **capillaries,** which unite to form larger diameter vessels, the **venules.** The arterioles, capillaries, and venules are collectively termed the **microcirculation.** The venules in the systemic circulation then unite to form larger vessels, the veins. The veins from the various peripheral organs and tissues unite to produce two large veins, the **inferior vena cava,** which collects blood from the lower portion of the body, and the **superior vena cava,** which collects blood from the upper half of the body. It is via these two veins that blood is returned to the right atrium. The pulmonary circulation is composed of a similar circuit. Blood leaves the right ventricle via a single large artery, the **pulmonary trunk,** which divides into the two **pulmonary arteries,** one supplying the right lung and the other the left. In the lungs, the arteries continue to branch, ultimately forming capillaries that unite into venules and then veins. The blood leaves the lungs via four **pulmonary veins,** which empty into the left atrium.





The different between Cardiac & Skeletal muscle:-

1-Cardiac muscle contain many branch of fiber, this will make muscle fiber closely related to each other, while skeletal muscle there is no such branches.

2- Present of intercalated disc.

3-The skeletal muscle need a nerve supply for the transport of stimulus & it doesn't exert except when stimulated.

4-**Refractory period:-** Cardiac muscle has a long refractory period which is not found is skeletal muscle, during the refractory if give any stimulus, it will not produce any response. The heart will not pass in tetanus.

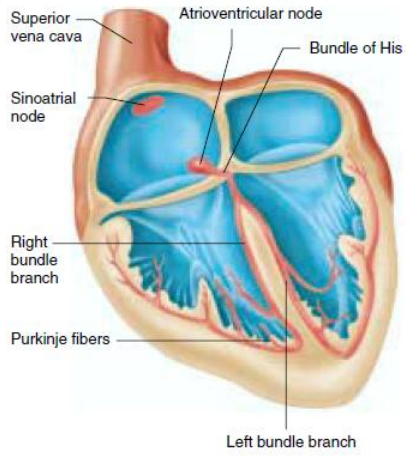
5-Cardiac muscle under the law of all or non, while skeletal muscle do not.

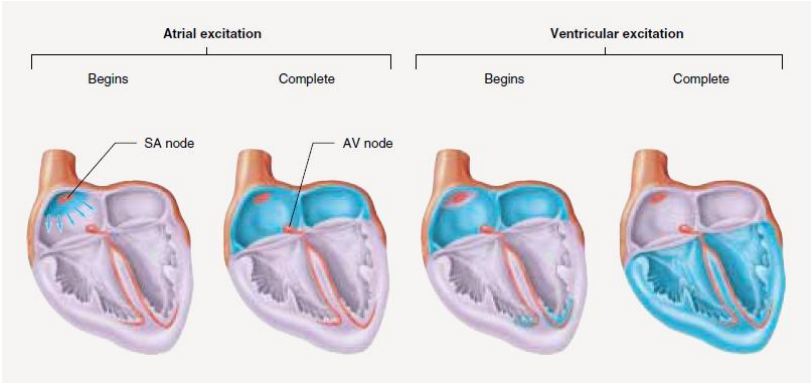
The Initiation :-In the mammals the heart beat started from a special node (fibers) associated in the upper part of the right atrium this node is called (**Sino-Atrial Node**) which is the **(Pacemaker)** of the heart while in the frog the pacemaker is (Sinus Venosus). It is an important part , the single fiber of the pacemaker or other part is spontaneously stimulate it does not each single fibers of the heart is beating spontaneously depending in herited Rhythum but pacemaker (leader).

- Conduction of heart beat (transportation):-

The impulse which is origin in the pacemaker of the heart should be transported (conduct) all over the heart in the first step the impulse which is originated from the sinoatrial node will be transported through the atrial muscle itself to another situated in the septum which separated the right atrial from a right ventricle this node is called the (atrioventricular node) which is consider as a **(Reserve pacemaker).** The impulse which reach the atrialventricular node should be transported through all parts of the ventricles in order to complete the cardiac cycle we needed a special system because the ventricle muscle 1- is very thick 2- the impulse cannot through to it because (the fibrous tissue which separated the atrium from ventricle).

The system is called **"pukinje system"** which is started from **[His bundle]**.This bundle will give two branches one go to the right ventricle and called **(right ventricular branch)** while the other is go to the left ventricle and called **(left ventricular branch)** each of these branches will give a rise network of fibers go to very fiber in the ventricular muscle this network called (**pukinje network)** when the impulse transported all over the heart will be contract and then relaxed each one contraction and relaxation is called(**Heart Beat**).





Cardiac Cycle:- The number of heart beats in one minutes is called the "**Heart rate**" during each heart beat the heart will eject volume of blood this volume is called **the stroke volume** and it is measure (c.c) or ml the volume which eject from heart beat during one minutes is called [**Cardiac output**].

Cardiac output=Stroke Volume × Heart rate (H.R.)

$$\text{Stroke Volume} = \frac{\text{Cardiac output}}{\text{Heart rate}}$$

Increase in heart rate is called **Tachycardia** while the decrease in Heart rate called **Bradycardia**.

Cardiac cycle can be divided in to two main periods:-
1-**Systol period**:- which is also mean period of ventricular contraction or period of ventricular ejection and this period divided into 3 sub periods:-

A-Period of isovolumetric ventricular contraction:-
During this period there is a contraction of ventricular muscle while all the valves are closed and the ventriculus fill with blood , this will increase the intraventricular pressure.

B-Rapid ventricular ejection:-
During period the aortic and pulmonary valve is open so the blood will be pump very rapidly from ventricle into aorta and pulmonary artery.

C-Period of slow ventricular ejection:-
During this period the pressure inside ventricle is decrease gradually due to ejection of blood from the ventricle to ward artery slow until the whole blood ejection to ventricle then the second period of cardiac cycle is started.

2-**Diastole Period:-** which is period of ventricular relaxation which is also called period of **ventricular filling**. During this period ventricle will fill with blood during 4 sub periods.

A-Isovolumetric ventricular relaxation:-
During this period there is relaxation in ventricular muscle, while they are empty of blood at the same time, the atrioventricular valve and the aortic and pulmonary valve are closed. This will decrease the pressure inside ventricles.

B-Rapid ventricular filling:-
During this period the atrioventricular valves opened while the pulmonary and aortic valves closed , so the blood will flow from atria ventricular in order to fill then.

C-Slow Ventricular filling:-
During this period the intraventricular pressure will increase gradually due to interance of blood from atria to ventricle, this will make the filling slower, this period is called slow ventricular filling.

D-Ventricular filling due to atria contraction:-
The atrial muscle will be contracted in order to sequese an extra blood which remain in atria into the ventricles and this period, the cardiac cycle will be finish and another cardiac cycle will be done.

Factors Assist on Occurrence of Cardiac Cycle

1-The presence & status valve.
2-Difference of pressure between atria & ventricle and between main arteries of heart, relation between pressure inside cardiac chamber & the main arteries.
3-The contraction of cardiac muscle**:-**The contraction of myocardium & relaxation which give the time to fill ventricle of blood.

Factors which Control Heart Rate

1-Sympathetic Nerve:-
Which one stimulated they will increase the heart rate, because it release in their nerve ending noradrenalin which stimulate directly the pacemaker of the heart.

2-Parasympathetic Nerve:-
Those nerve release in their ending acetylcholine which decrease heart rate due to direct action of this material on pacemaker.

3-Some Hormone such adrenaline:-
It secreted from adrenal medulla, increase the heart rate also force of contraction of myocardium. Noradrenalin secreted from adrenal medulla. If we take a blood sample you can see adrenaline & noradrenalin together which come from sympathetic nerve.

4-Overfilling of right atrium of blood:-
Which induce stretch on the sinoatrial node and increase heart rate.

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Autorhythmicity:- The ability of the heart to generate signals that trigger its contractions on periodic basis that is to generate its own rhythm.

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"Cardiac Action Potential"

-The resting membrane is much more permeable to K^+ ion that Na^+ ion, therefore the resting membrane potential is much closure to the K^+ equilibrium potential (-90mv) than Na^+ ion equilibrium potential (+60mv).

-The depolarization phase of action potential is due to positive feedback increase in Na^+ ion permeability caused by the opening of Na^+ valtage gate channel so the channel are opened by depolarization.

-At the same time the permeability to K^+ ion decrease as K^+ channel close and this contributed to the membrane depolarization.

-The increase of Na^+ ion permeability is very transient, since the Na^+ channel quikly close again. In cardiac muscle the return of Na^+ ion permeability towards its resting value is not combined by membrane repolarization.

The membrane remain depolarization at 0mv the reason for this continue depolarization.

1- K^+ ion permeability stay below the resting value so K^+ channel remain closed.

2-There is a marked increase in the membrane permeability to Ca^{+2}

In myocardial cell, the original membrane depolarization causes volatage gated Ca^{+2} channel in plasma membrane to open which result in a flow of Ca^{+2} ion down there electrochemical gradient into the cell. These channel are refer to slow channel because there is a delay in their opening. The flow of positive calcium ions into the cell just balance the flow of positive potassium change out of the cell & keeps the membrane depolarization at the plateau valve Repolarization does occur when the permeability of Ca^{+2} & K^+ return to their original state, that is when the slow channel of Ca^{+2} close and the K^+ channel re open.

The action potential of atrial cell similar to venticular but the duration phase is shorter except SA node.

Heart Sound

Any person when he put on its ear on the left side of thorax just about the heart, he will heard two normal heart sounds these also sound we can heard when put stethoscope on the site of the heart in the thorax.
These 2 sounds are:-

1-The first heart sound:- which is similar to the word **Lub**, this sound due to closure of the bicusp (mitral) & tricusp valve (of two atrioventricular valve) and this sound is heard during the beginning of systol period this sound is also called Systolic sound, it is longer & strong and less sharp.
2-The second heart sound:- which is similar to the word **Dub**, this sound is due to closure of the aortic & pulmonary valve when the blood of artery hit the valve & gate sound, this sound is heard during beginning of period of diastol, thus is also called diastolic sound.
This sound is shorter than first & its strength is less but its sharp.
There are two another normal heart sound but we can't heard by stethoscope, but we can record them by a special apparatus is called **phone cardiography**.
3- The third heart sound:- which due to trance of blood from atria to ventricles & the vibration of ventricle wall.
4-The fourth heart sound:- The sound occurs due to contraction of the atria & the flow of blood from atria to ventricle.
Note :- The fourth heart sound is called also **weaker sound**.
There are abnormal heart sound which is called **murmrs** these sounds are hear when there is defect in the valves.
The defect in the valve are in 2 types:-
1-Valvular insufficiency or incompetence:- which occur in some pathological condition such as **septicemia** and **rheumatic fever**.
During these cases may be any of the valve is not closed properly& some the blood will return in opposite direction.
The return of the blood in opposite direction cause abnormal sound , insufficiency may occur in any of valve, so it will be referred or known after the name of valve. such as mitral insufficiency or incompetence, tricuspid incompetence or pulmonary semilunar or aortic semilunar valve insufficiency or incompetence.
2-Valvular stenosis:- This condition is due to passage the blood through astenoid opening ,the stenosis due to accumulation and deposition of cholesterol & properly glucose near the opening of the remain arteries of valve & take the name of the effected valve such as mitral stenosis or tricuspid stenosis or pulmonary semilunar or aortic semilunar valve stenosis.

Some Drug which act on the Heart

1-Atropine:- Which increase the heart rate because it cause a paralysis of parasympathetic nerve

2-Muscarine:-Which cause decrease in the heart rate because it stimulate the parasympathetic nerve.

3- Choline & its derivative:- Which slow the heart because it decrease the heart rate.

4-Nicotin:- Which act at the beginning can stimulation of parasympathetic nerve, so it will decrease the heart rate & later will cause paralysis of parasympathetic, so it will increase the heart rate.

5-Digitalis:-Which is most important drug use by physician when the heart stop, it will increase the heart rate and force of contraction. When the dose is high it will cause separation on atria from ventricle (complete heart block).

Work of the heart

1-The production of mechanical energy is required in the heart to compensate for the dissipation of energy as heat in the circulation.

2-The amount of energy supplied to the circulation by the heart is measured by the mechanical work of the heart, which is calculated from the product of the ventricular pressure and the ventricular output.

3-The production of this work by the heart muscle involves the maintenance of tension, and this demands a increased steady supply of energy even id no physical work is done.

4- The total load of the heart, measured by the cardiac oxygen consumption, therefore depends on the sum of two terms: the mechanical work of the heart and maintenance heat(tension-tin integral).

5-of these two terms, the maintenance heat is much greater than the external work. As consequence, the mechanical efficiency of the heart is always very low, even though it increase markedly as the work of pumping is increased.

6-These principle have important clinical application to cardiac mild exercise, which increase the work but does not increase the load greatly, is not so dangerous as increases in blood pressure, heart rate and size of the heart(cardiac dilation). This last factor depends on the law Laplace, according to which the larger the heart, the greater is the muscular tension required to produce a given systolic pressure .

Work of the heart:- It can be calculated by the forma of the followed.

$$\textbf{The work} = \frac{PV + WV_2}{2G(980)} = PV + \frac{WV_2}{2G}$$

P=is the mean arterial blood pressure.

V=is the stroke volume(70).

W=The weight of the blood in the ventricles $1g/cm^3$.

V_2=This speed of the flow of the blood(520).

G=acceleration of the gravity (980).

The work of the heart can be also calculated by multiply the cardiac output by main arterial blood pressure.

The work = C.O × Mean blood pressure × 13.6 = g/cm(unit of the work)

C.O=5L

Artery blood pressure = 100cm =10cm × 13.6

$\frac{WV_2}{2G}$ ⟶ Refer to potential energy.

The O_2 consumption of the heart

Which consumed about 8% of total of O_2 consumption of the body. If the body consume 250ml of O_2this mean the heart will consume about 20ml

of $O_2$and if we known that each ml of O_2 will produce about 5 calorie and each calorie give about 0.247 kg/m energy (work).
We can calculate the work of the heart.

How the can test the function of the heart ?
There are two test for function of heart:-
1-Schwlong test :- which depend on the comparison of the blood pressure, heart rate, respiration rate during exercise and rest state. (B.P.,H.R.,R.R.) during exercise and rest state.
2-:- which depend testing of the function during inflation or increase

Burger test resistance in pulmonary circulation by blowing tube connecting with mercuric manometer in the blowing pressure 40-60mm and recording of the blood pressure of the body. (arterial blood pressure)
In the low tonic heart (weak heart)the blood pressure will decline sharply below normal in the beginning and then it will rise just about normal while in the normal heart the blood pressure decline slightly below normal in the beginning and then it rise above normal.
In the sport heart it will rise sharply above normal.

Cardiac output

Cardiac output (CO):- depends on the number of heart beats / min.(heart rate, HR) and the volume of blood ejected from one ventricle with each beat (stroke volume, SV). It can be calculated as follows:

$$Co=HR \times SV$$

For an adult at rest, the normal resting heart rate is a round 72 beats / minute and the stroke volume is 70 ml(0.07 liter), thus a cardiac output is
Co = 72 beat/ min × 0.07 liter / beat = 5.0 liter / min.
During periods of exercise, the heart rate and stroke volume both increase. The resulting increase in cardiac output, which can go up to 35 liter / min. in trained athletes, helps to increase the rate at which blood delivers oxygen and nutrients to exercising muscle.

-Measurement of cardiac output
1- It could be directly that mean we depend on stroke volume and H.R. by using flow meter on one artery measure the S.V. which than multiply by H.R. to obtain the C.O.
Direct method:- for measurement of cardiac output by make catheter on aorta or pulmonary artery to measure blood volume by flow meter.

$$S.V. \times H.R. = C.O.$$

Indirect methods
1-Fick method:- This method depend on O_2 consumption by the lung or on CO_2 and difference between arterial and venous O_2.

$$C.O. = \frac{O_2 \text{ consumption}}{\text{Arterial } O_2 - \text{Venous } O_2}$$

$$C.O. = \frac{Co_2 \text{ consumption}}{\text{Arterial } O_2 - \text{Venous } O_2}$$

This calcultion depend on pulmonary artery and pulmonary vein in this case the blood in the pulmonary artery is refere to the venous blood and the blood in the pulmonary vein is refer to the arterial blood.

2-Indirect dilution techneque:-

Which depend injection of a known concentration of a dye or isotop into a vein and then measure the concentration of that dye in the blood after constant time(1min.).

$$C.O = \frac{\text{a mount of dye injection the volume}}{\text{Conc. Of dye in the blood}}$$

$C_1V_1=C_2V_2$

The usuall dye or substance which is used should have some criteria:-

1- not toxic

2-not absorbe or secreted from body

3-should stay long time in circulation:-

Hamelton method used the dilution techneque but he measured the concentration of dye in intervals of time and draw a cure for the concentation then calculate the cardiac output.

$$\text{Cardiac output} = \frac{\text{amountof dye injection}}{\text{Area under the curve} \times \text{caliperation factor}}$$

*The best dye used (endocyanin green) or isotops.

When we use dye we should use spectrophotometer to measure the concentration of dye while if we use isotops the radio counter is used the measure the amount of radiation/min.

Cardiac Reserve

The shifting in the heart is occur when there is changes in one of ventricles. The amount of blood which enter the heart is equal to leave the heart and amount that eject from right ventricle equal to that ejected from left ventricle so far the very simple reason if any small change in amount of blood which is ejected from the left ventricle (0.1ml) this will cause a shift of the blood to systemic circulation and advansverse , the changing in the right ventricle this will cause a shift of blood to the pulmonary circulation and death may happen within 10 days.

When such changes occur in the right ventricle as soon as the lung cause pressure on pulmonary artery to push more amount of blood and then cause pressure on pulmonary veins to return more amount of blood to the heart lead to increase amount of blood which return to the left side of the

heart which then ejected in the systemic circulation causes of changes in the amount of blood ejection from the heart :-

1-increase contractility of the heart lead to increase accumulation large amount of blood in capillary blood vessels and lead to odema and engorgement.

2-muscular stress lead to increase change in the left

3- valvular defect.

Cardiac Compensation

Cardiac Compensation:-The ability of the heart to increase its output even beyond the cardiac reserve (through increasing the tension of cardiac muscle fiber which lead to increase the energy and result in increase cardiac output.

When there is valve in the aortic or pulmonary valve defect(incompetence) such as when there will be regurgitation of blood from the aorta or the pulmonary artery toward the left or right ventricle and we said this will cause increase in the ventricular filling and this will increase liberation energy in order to increase the volume of the blood ejected this is possible in normal person but it is impossible low toned heart.

Contractility and amount of the blood when this case for continue for long time cause a hypertrophy in the ventricular muscle, right or left),this will increase the work done by heart in order to eject enough blood to the tissue (sufficient amount of the blood)

Stenosis in mitral valve → in left atria ventricular(mitral or bicuspid valve) →

Pulmonary venous stasis → lung congestion + odema or pulmonary stenosis → ↓ vein oxygenated blood to left atria → ↓ oxygenated left ventricle.

hypoxia → cyanosis + congestion of lung and odema →

ventricle → aorta pulmonary venous stasis.

Frank- Starling Law

When an extra amount of blood flows into the ventricles the cardiac muscle itself is stretched to greater length. This is turn causes the muscle to contract with increased force because the actin & myosin filaments are brought to a more nearly optimal degree of overlap for force generation, therefore, the ventricle because of its increased pumping, automatically pump the extra blood into the arteries. The ability of stretched muscle, up to an optimal length, to contract with increased work output is characteristic of all striated muscle & in addition to important effect of

lengthening the heart muscle, still another factor increased heart pump when its volume is increased. Stretch of the right atrial wall directly increased the heart rate by 10 to 20% this too helps increase the amount of blood pumped each minute, although is contribution is much less than that of the Frank-starling mechanism.

Starling Law:- The work done by the heart it relation conversely of the length of the muscle fiber.

1-Failure of closure of ductus arteriosus lead to happen patent ductus arteriosus →

Poor of gain & ↑ breathing → C.H.F.

Congenital heart defect (**C.H.D**) or **congenital heart anomaly**:- is a defect in the structure of the heart and great vessels which is present at birth. Many types of heart defects exist, most of which either obstruct blood flow in the heart or vessels near it, or cause blood to flow through the heart in an abnormal pattern. Other defects, such as long QT syndrome, affect the heart's rhythm. Heart defects are among the most common birth defects and are the leading cause of birth defect-related deaths. Many defects do not need treatment, but some complex congenital heart defects require medication or surgery.

Important causes of congenital anomalies in heart

1- Infection of virus :- when mother infected with virus during first month of pregnancy when the heart started development.

2-Infected mother with measles during three first months.

3-Hereditary in state of twin.

4- Numbers of a Ventricular septal defect (VSD), atrial septal defects, and tetralogy of Fallot are the most common congenital heart defects seen in the ventricles association. Less common defects in the association are truncus arteriosus and transposition of the great arteries.

Fetal Circulation

The blood of the fetus will be supplied with oxygen by the blood of the mother through the placenta, the oxygenated blood arrive to the fetus from the placenta by umbilical vein this vein will enter to fetal body in the hilus , this blood go directly to the liver through a duct called *ductus venosus* and then it go to where posterior vena cava where it mix with unoxygenated blood come from posterior part of body and flow in the inferior vena cava until it meet the other part of body which form anterior part of body by anterior vena cava.
The blood become semi oxygenated when it enter the right atrium.
A little part of blood will pass from right atrium to left atrium through a forman called **Bursa ovali** or **Fossa ovali**.
-The major part of blood from right atrium to right ventricle and from the it will be pump to inactive lung by the pulmonary artery, it will supply the lung by oxygen and nutrient and then it will return to the left atrium where it mix with blood come from right atrium and then it will enter to the left ventricle.
From left ventricle the blood will be ejected all over the body by the aorta.
In one point the aorta run adjucent to the pulmonary artery and there is a duct between them called **Ductus arteriosis** which allow some of the blood to pass pulmonary artery to aorta.
-The blood return back to the placenta of the mother by the umbilical artery.

Changes Occur After Birth

1- Closure of fossa ovali
2- Closure of ductus venosus.
3- Closure of ductus arteriosus.
4- Oxygenation of blood will take place in lungs & it become active and changes to spongious tissue instead of elastic tissue due to flow, these will stimulate the inspiratory center.
5- Areflex vasoconstriction in umbilical artery in order to stop the loss of blood.

Congenital anomalies

1-Failure in Closure of foramen alvali.
2- Failure in closure of ductus venosus.
3-Failure in closure of ductus ateriosus.
4-Defect in formation of septum which separate the two ventricles , so the septum may be opened in a point after birth dueto

Fetal Circulation

The **fetal circulation** is the circulatory system of a animal fetus, often encompassing the entire fetoplacental circulation which includes the umbilical cord and the blood vessels within the placenta that carry fetal blood. The fetal circulation works differently from that of born animals, mainly because the lungs are not in use: the fetus obtains oxygen and nutrients from the mother through the placenta and the umbilical cord.

The core concept behind fetal circulation is that fetal hemoglobin has a higher affinity for oxygen than does adult hemoglobin, which allows a diffusion of oxygen from the mother's circulatory system to the fetus. The circulatory system of the mother is not directly connected to that of the fetus, so the placenta functions as the respiratory center for the fetus as well as a site of filtration for plasma nutrients and wastes. Water, glucose, amino acids, vitamins, and inorganic salts freely diffuse across the placenta along with oxygen. The umbilical arteries carry blood to the placenta, and the blood permeates the sponge-like material there. Oxygen then diffuses from the placenta to the chorionic villus, an alveolus-like structure, where it is then carried to the umbilical vein.

Circuit

Blood from the placenta is carried to the fetus by the umbilical vein. Less than a third of this enters the fetal *ductus venosus* and is carried to the inferior vena cava, while the rest enters the liver proper from the inferior border of the liver. The branch of the umbilical vein that supplies the right lobe of the liver first joins with the portal vein. The blood then moves to the right atrium of the heart. In the fetus, there is an opening between the right and left atrium (the *foramen ovale*), and most of the blood flows through this hole directly into the left atrium from the right atrium, thus bypassing pulmonary circulation. The continuation of this blood flow is into the left ventricle, and from there it is pumped through the aorta into the body. Some of the blood moves from the aorta through the internal iliac arteries to the umbilical arteries, and re-enters the placenta, where carbon dioxide and other waste products from the fetus are taken up and enter the maternal circulation. Some of the blood entering the right atrium does not pass directly to the left atrium through the *foramen ovale*, but enters the right ventricle and is pumped into the pulmonary artery. In the fetus, there is a special connection between the pulmonary artery and the aorta, called the *ductus arteriosus*, which directs most of this blood away from the lungs (which aren't being used for respiration at this point as the fetus is suspended in amniotic fluid).

Circulation Dynamic

Blood vessels:- Blood flow in the right and left ventricle into the pulmonary and aortic and into the small arteries and then reach into return back right and left atria through vena cava and pulmonary vein.
((The blood flow from the heart to the heart))
The flow of the blood in blood vessels in govern by many factor:-
1-Characterized of the blood of fluid which include
a-The viscosity.
b-The laminar flow.
2-Characterized of the blood vessels which include
a-Length of the blood vessels.
b-Diameter radius.
c-Elasticity.
3-Blood pressure:- so the gravid poiseuilles Law which stand the flow the blood.

Poiseuilles Law = Flow = $\frac{\Delta p\ (P1 - P2)\ r^4}{L \times V}$

P = pressure
L= length
V= viscosity
The quantity Δp, the size of the pressure gradient, represent the driving force that pushes the flow of liquid the rough blood .vessels.

Characterized of the blood as fluid:-
A-Viscosity of blood:- Colloid fluid because it contain plasma protein as well as other material such as glucose in the plasma and it contain in the blood, red blood corpuscular(cells of the blood).
-Plasma protein specially albumin affect on flow of blood conversely of the proportionality with viscosity of the blood. Viscosity effect on the flow of blood in the blood vessels and when the viscosity increase the flow will decrease that to say viscosity is reverser with flow.
1-Blood pressure:-Directly proportional to the viscosity.
2- Resistance:-Directly proportional to viscosity. Fraction between blood fluid and wall of the blood vessels and fraction between the component of the blood fluid (shearing force).
3-Diameter affect of viscosity.
4-Tempeature affect of the viscosity.
-Viscosity and the Manner in which Blood Flows:-
Force of attraction between blood and the blood vessel wall prevent the infinitesimally thin layer of plasma that is in contact with the wall from moving, even when the blood farther away is flowing.
-Measurement of viscosity viscometers:-

B-Laminar flow:- The blood will not flow in blood vessels as one layer in the same speed, but it will form lamina(layer).
The first lamina adjacent with the wall of blood vessels is flow in very slow speed in seem to be stop close the wall.
The second lamina will flow faster than first one because fraction between the blood in this lamina & the wall of the vessels is decrease ender go on until it reach the center of the blood vessels where the lamina in center has the highest speed because the fraction diminution.

2-Characterized of blood vessels:-

a-Length of blood vessels:- Under the constant pressure of fluid of the tube will be higher within beginning of the tube and decrease in the far of the tube. The flow of the blood reversely proportional.

b-The Diameter:- When the diameter increase it will lead to blood flow easy & faster than the narrow blood vessels that to say the flow of directly proportional to diameter of blood vessels.

-**Radius of the blood vessels:-** Directly proportional of flow.

-**Resistance:-** Is reversely proportion with radius of the blood vessels, blood pressure.

c- Elasticity:- We known the elastic tissue. The blood vessel is elasticity is more than in big artery because these big arteries high pressure with stand the high pressure of the ejection of the blood from or by the heart to keep in the blood vessels of the period of the diastolic.

Elasticity of the artery:-The elasticity of blood vessels which effect the flow are flexible that to say the blood vessels will dilate in order to maintain the blood during the period of systole & it will return back to normal diameter during the period of diastole. This will add an extra pressure during the period of diastole which assist in the flow of blood during this period, so the blood will not return back in opposite direction.
When elasticity of blood vessels increase it will become more flexible and there is very obvious in big arteries.

3-Blood Pressure:-

Blood Pressure:-

Which is very important factor effect on the blood vessels. The blood will flow from the point of high pressure to low pressure graduate, so the flow of blood is directly proportional to the difference of pressure between two points(Δp).

Blood is the pumping activity of the heart or the forces ejection of the blood vessels(arties) the pressure depending mainly on two factors.

a-Cardiac output:- Which mean the volume of blood ejected from the heart during one minute & when cardiac output increase this will increase blood pressure and cardiac output depending on two factors **strock volume** & **heart rate** so when the strock volume increase or heart rate increase or both, this lead to increase cardiac output& finaly increase **blood pressure**.

b-Peripheral Resistance:- which mean resistance of the peripheral blood vessels especially the arterioles to the flow of blood, this resistance of peripheral blood vessels to the flow of blood depend mainly on diameter of peripheral blood vessels, when the diameter decrease of blood vessels this will increase the resistance to the flow of blood while the diameter increase it will decrease the peripheral resistance, that to say peripheral resistance is reversity proportional to the diameter of peripheral blood vessels.

Viscosity of the blood increase it will increase the resistance & finally lead to increase blood pressure.

The Blood Pressure has two ends:-

A-Systolic Blood Pressure:-Which is recorded during the period of systole, that to say period of contraction or ejection of blood from heart.

B-Diastolic Blood Pressure:- Which is recorded during the period of diastolic that to say period of ventricular dilation or period of filling of heart.

The difference between systolic &diastolic called **(The pressure pulse)**

pressure pulse = **Syst. Pre. - Dia. Pre**

Measurement of Blood Pressure

The blood pressure can be measured either directly or indirect.

1-Direct Method:-More accurate which mean the measrment of blood pressure from the inside of blood vessels (big artery).
This method was first used by (stiven holl) who in search to high glass tube filled with the water in of the hours & the recording the difference in the highness of the water which rise up in the tube & he recorded the blood pressure as acentimeter of water after that the water was replaced by a mercury & the blood pressure will record as acentimeter mercury.
Electronic more accurate & more sensitive and we can record blood pressure minute. It made by catheter attached with pressure transducer & this (P.tran)is glass ball heparinized saline , this contain a very thin rubber membrane in the middle . The blood pressure will induce a wave (vibration wave) in the rubber membrane, this wave very small and can not be record.
This is why the pressure transducer attached with amplifier (blood pressure ampilifier).Then the ampilifier attached with electronic recorder which record blood pressure as wave on graph paper.
2-Indirect Method:-Which record the blood pressure from outside of the body by using sphegmomanometer. This method depend upon applying & in outside pressure above arterial blood presssure on a main artery so the flow of the blood in this artery will be stopped and then we reduce outside pressure slowly untile we hear the flow of blood for the first time by stethoscope or feel the pulse by the finger.
This will record the systolic blood pressure we continue reducing the outside pressure until the sound of the flow disappear, this point will be recorded the diastolic blood pressure, but diastolic blood pressure can not be record if we use the palpation of the pulse in this case we can record the systolic blood pressure.

Factor which effect or change alter of Blood Pressure

There are many factor which alter of blood pressure the most important factor are:-
1-Age:- The blood pressure increase in old age because will be thickness of wall of arteries& it will loss its elasticity, this will increase the blood pressure, this due to precipitation of calcium, cholesterol & other minerals found in blood vessels(arteries).

2- Embryonic development:-The blood pressure will increase gradually when the embryonic develop in its age this will due to 2 main factors that increase in blood volume ⟶ gradually & also of the change ⟶ occur in the
Blood vessels wall.

3- Body size:- The blood pressure increase in big size body while it decrease in small size.

4-Some drug & Chemical:- Effect on blood pressure such as alcohol which increase the blood pressure .Cholin derivative will decrease blood pressure & this decrease peripheral resistance.

5-Emotion:- Increase the blood pressure because it effect on secretion of some organ such as adrenalin so it will increase the blood pressure.

6-Position of body:- Effect on blood pressure, so the pressure higher in setting position than during recumbent.

7-Exerices:-Which also increase the blood pressure because it contraction of movement of ~~muscle & v~~ein this increase the blood pressure.

8-Sex:- In male, the blood pressure will be increase than female because in female found level of progesterone is high, so lead to dilation of blood vessels this lead to decrease blood pressure.

Control of Blood Pressure

Blood Pressure

Blood pressure (**BP**), sometimes referred to as **arterial blood pressure**, is the pressure exerted by circulating blood upon the walls of blood vessels, and is one of the principal vital signs. When used without further specification, "blood pressure" usually refers to the arterial pressure of the systemic circulation. During each heartbeat, blood pressure varies between a maximum (systolic) and a minimum (diastolic) pressure. The blood pressure in the circulation is principally due to the pumping action of the heart. Differences in mean blood pressure are responsible for blood flow from one location to another in the circulation. The rate of mean blood flow depends on both blood pressure and the resistance to flow presented by the blood vessels. Mean blood pressure decreases as the circulating blood moves away from the heart through arteries and capillaries due to viscous losses of energy. Mean blood pressure drops over the whole circulation, although most of the fall occurs along the small arteries and arterioles. Gravity affects blood pressure via hydrostatic forces (e.g., during standing), and valves in veins, breathing, and pumping from contraction of skeletal muscles also influence blood pressure in veins.

Blood pressure without further specification usually refers to the systemic arterial pressure measured at a person's upper arm and is a measure of the pressure in the brachial artery, the major artery in the upper arm. A person’s blood pressure is usually expressed in terms of the systolic pressure over diastolic pressure and is measured in millimetres of mercury (mm Hg), for example 120/80. It is also expressed as the amount over normal atmospheric pressure (760 mm Hg), so a blood pressure of 120 mm Hg would actually be 880 mm Hg of true pressure.

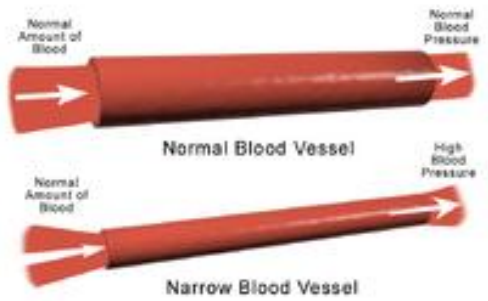
Blood pressure varies in healthy people and animals, but its variation is under control by the nervous and endocrine systems. Blood pressure that is pathologically low is called hypotension, and that which is pathologically high is hypertension. Both have many causes and can range from mild to severe.

Normal range of blood pressure

While average values for arterial pressure could be computed for a given population, there is often a large variation from person to person; arterial pressure also varies in individuals from moment to moment. Additionally, the average of any given population may have a questionable correlation with its general health; thus the relevance of such average values is equally questionable. However, in a study of 100 human subjects with no known history of hypertension, an average blood pressure of 120/80 mm Hg was found, which are currently classified as desirable or "normal" values. Normal values fluctuate through the 24-hour cycle, with highest readings in the afternoons and lowest readings at night.

Various factors, such as age and sex, influence a person's average blood pressure and variations in it. In children, the normal ranges are lower than for adults and depend on height. As adults age, systolic pressure tends to rise and diastolic tends to fall. In the elderly, blood pressure tends to be above the normal adult range, largely because of reduced flexibility of the arteries. Also, an individual's blood pressure varies with exercise, emotional reactions, sleep, digestion, time of day and circadian rhythm.
Differences between left and right arm blood pressure measurements tend to be random and average to nearly zero if enough measurements are taken. However, in a small percentage of cases there is a consistent difference greater than 10 mm Hg which may need further investigation, e.g. for obstructive arterial disease.
The risk of cardiovascular disease increases progressively above 115/75 mm Hg. In the past, hypertension was only diagnosed if secondary signs of high arterial pressure were present, along with a prolonged high systolic pressure reading over several visits. Regarding hypotension, in practice blood pressure is considered too low only if noticeable symptoms are present.
Clinical trials demonstrate that people who maintain arterial pressures at the low end of these pressure ranges have much better long term cardiovascular health. The principal medical debate concerns the aggressiveness and relative value of methods used to lower pressures into this range for those who do not maintain such pressure on their own. Elevations, more commonly seen in older people, though often considered normal, are associated with increased morbidity and mortality.

Physiology



Blood Pressure Blood Flow

Illustration demonstrating how vessel narrowing, or vasoconstriction, increases blood pressure.
There are many physical factors that influence arterial pressure. Each of these may in turn be influenced by physiological factors, such as: diet, exercise, disease, drugs or alcohol, stress, and obesity.

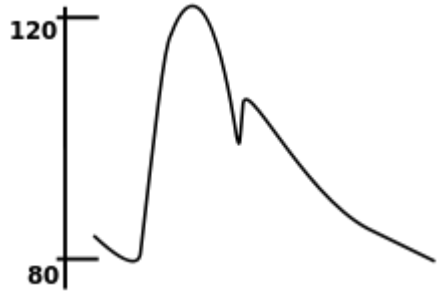
Some physical factors are:

- Volume of fluid or blood volume, the amount of blood that is present in the body. The more blood present in the body, the higher the rate of blood return to the heart and the resulting cardiac output. There is some relationship between dietary salt intake and increased blood volume, potentially resulting in higher arterial pressure, though this varies with the individual and is highly dependent on autonomic nervous system response and the renin-angiotensin system.
- Resistance. In the circulatory system, this is the resistance of the blood vessels. The higher the resistance, the higher the arterial pressure upstream from the resistance to blood flow. Resistance is related to vessel radius (the larger the radius, the lower the resistance), vessel length (the longer the vessel, the higher the resistance), blood viscosity, as well as the smoothness of the blood vessel walls. Smoothness is reduced by the buildup of fatty deposits on the arterial walls. Substances called vasoconstrictors can reduce the size of blood vessels, thereby increasing blood pressure. Vasodilators (such as nitroglycerin) increase the size of blood vessels, thereby decreasing arterial pressure. Resistance, and its relation to volumetric flow rate (Q) and pressure difference between the two ends of a vessel are described by Poiseuille's Law.
- Viscosity, or thickness of the fluid. If the blood gets thicker, the result is an increase in arterial pressure. Certain medical conditions can change the viscosity of the blood. For instance, anemia (low red blood cell concentration), reduces viscosity, whereas increased red blood cell concentration increases viscosity. It had been thought that aspirin and related "blood thinner" drugs decreased the viscosity of blood, but instead studies found that they act by reducing the tendency of the blood to clot.

In practice, each individual's autonomic nervous system responds to and regulates all these interacting factors so that, although the above issues are important, the actual arterial pressure response of a given individual varies widely because of both split-second and slow-moving responses of the nervous system and end organs. These responses are very effective in changing the variables and resulting blood pressure from moment to moment.

Moreover, blood pressure is the result of cardiac output increased by peripheral resistance: *blood pressure = cardiac output X peripheral resistance*. As a result, an abnormal change in blood pressure is often an indication of a problem affecting the heart's output, the blood vessels' resistance, or both. Thus, knowing the patient's blood pressure is critical to assess any pathology related to output and resistance.

Pulse pressure



Curve of the arterial pressure during one cardiac cycle

The up and down fluctuation of the arterial pressure results from the pulsatile nature of the cardiac output, i.e. the heartbeat. The pulse pressure is determined by the interaction of the stroke volume of the heart, compliance (ability to expand) of the aorta, and the resistance to flow in the arterial tree. By expanding under pressure, the aorta absorbs some of the force of the blood surge from the heart during a heartbeat. In this way, the pulse pressure is reduced from what it would be if the aorta wasn't compliant. The loss of arterial compliance that occurs with aging explains the elevated pulse pressures found in elderly patients.

The pulse pressure can be simply calculated from the difference of the measured systolic and diastolic pressures,

$P_{\text{pulse}} = P_{\text{sys}} - P_{\text{dias}}$.

Arm–leg gradient

The *arm–leg (blood pressure) gradient* is the difference between the blood pressure measured in the arms and that measured in the legs. It is normally less than 10 mm Hg, but may be increased in e.g. coarctation of the aorta.

Vascular resistance

The larger arteries, including all large enough to see without magnification, are conduits with low vascular resistance (assuming no advanced atherosclerotic changes) with high flow rates that generate only small drops in pressure. The smaller arteries and arterioles have higher resistance, and confer the main blood pressure drop across major arteries to capillaries in the circulatory system.

Vascular pressure wave

Modern physiology developed the concept of the vascular pressure wave (VPW). This wave is created by the heart during the systole and originates in the ascending aorta. Much faster than the stream of blood itself, it is then transported through the vessel walls to the peripheral arteries. There the

Vascular pressure wave

Modern physiology developed the concept of the vascular pressure wave (VPW). This wave is created by the heart during the systole and originates in the ascending aorta. Much faster than the stream of blood itself, it is then transported through the vessel walls to the peripheral arteries. There the pressure wave can be palpated as the peripheral pulse. As the wave is reflected at the peripheral veins, it runs back in a centripetal fashion. When the reflected wave meets the next outbound pressure wave, the pressure inside the vessel rises higher than the pressure in the aorta. This concept explains why the arterial pressure inside the peripheral arteries of the legs and arms is higher than the arterial pressure in the aorta, and in turn for the higher pressures seen at the ankle compared to the arm with normal ankle brachial pressure index values.

Regulation

The endogenous regulation of arterial pressure is not completely understood, but the following mechanisms of regulating arterial pressure have been well-characterized:

- Baroreceptor reflex: Baroreceptors in the high pressure receptor zones detect changes in arterial pressure. These baroreceptors send signals ultimately to the medulla of the brain stem, specifically to the Rostral ventrolateral medulla (RVLM). The medulla, by way of the autonomic nervous system, adjusts the mean arterial pressure by altering both the force and speed of the heart's contractions, as well as the total peripheral resistance. The most important arterial baroreceptors are located in the left and right carotid sinuses and in the aortic arch.[31]
- Renin-angiotensin system (RAS): This system is generally known for its long-term adjustment of arterial pressure. This system allows the kidney to compensate for loss in blood volume or drops in arterial pressure by activating an endogenous vasoconstrictor known as angiotensin II.
- Aldosterone release: This steroid hormone is released from the adrenal cortex in response to angiotensin II or high serum potassium levels. Aldosterone stimulates sodium retention and potassium excretion by the kidneys. Since sodium is the main ion that determines the amount of fluid in the blood vessels by osmosis, aldosterone will increase fluid retention, and indirectly, arterial pressure.
- Baroreceptors in low pressure receptor zones (mainly in the venae cavae and the pulmonary veins, and in the atria) result in feedback by regulating the secretion of antidiuretic hormone (ADH/Vasopressin), renin and aldosterone. The resultant increase in blood volume results an increased cardiac output by the Frank–Starling law of the heart, in turn increasing arterial blood pressure.

These different mechanisms are not necessarily independent of each other, as indicated by the link between the RAS and aldosterone release. Currently, the RAS is targeted pharmacologically by ACE inhibitors and angiotensin II receptor antagonists. The aldosterone system is directly targeted by spironolactone, an aldosterone antagonist. The fluid retention may be targeted by diuretics; the antihypertensive effect of diuretics is due to its effect on blood volume. Generally, the baroreceptor reflex is not targeted in hypertension because if blocked, individuals may suffer from orthostatic hypotension and fainting.

Measurement

A medical student checking blood pressure using a sphygmomanometer and stethoscope.

Right position for taking blood pressure Arterial pressure is most commonly measured via a sphygmomanometer, which historically used the height of a column of mercury to reflect the circulating pressure. Blood pressure values are generally reported in millimetres of mercury (mm Hg), though aneroid and electronic devices do not contain mercury.

For each heartbeat, blood pressure varies between systolic and diastolic pressures. Systolic pressure is peak pressure in the arteries, which occurs near the end of the cardiac cycle when the ventricles are contracting. Diastolic pressure is minimum pressure in the arteries, which occurs near the beginning of the cardiac cycle when the ventricles are filled with blood. An example of normal measured values for a resting, healthy adult human is 120 mm Hg systolic and 80 mm Hg diastolic (written as 120/80 mm Hg, and spoken as "one-twenty over eighty").

Systolic and diastolic arterial blood pressures are not static but undergo natural variations from one heartbeat to another and throughout the day (in a circadian rhythm). They also change in response to stress, nutritional factors, drugs, disease, exercise, and momentarily from standing up. Sometimes the variations are large. Hypertension refers to arterial pressure being abnormally high, as opposed to hypotension, when it is abnormally low. Along with body temperature, respiratory rate, and pulse rate, blood pressure is one of the four main vital signs routinely monitored by medical professionals and healthcare providers.

Measuring pressure invasively, by penetrating the arterial wall to take the measurement, is much less common and usually restricted to a hospital setting.

Palpation

A minimum systolic value can be roughly estimated by palpation, most often used in emergency situations, but should be used with caution. It has been estimated that, using 50% percentiles, carotid, femoral and radial pulses are present in patients with a systolic blood pressure >

70 mm Hg, carotid and femoral pulses alone in patients with systolic blood pressure of > 50 mm Hg, and only a carotid pulse in patients with a systolic blood pressure of > 40 mm Hg.
A more accurate value of systolic blood pressure can be obtained with a sphygmomanometer and palpating the radial pulse. The diastolic blood pressure cannot be estimated by this method. The American Heart Association recommends that palpation be used to get an estimate before using the auscultatory method.

Auscultatory

Auscultatory method aneroid sphygmomanometer with stethoscope

Mercury manometer

The auscultatory method (from the Latin word for "listening") uses a stethoscope and a sphygmomanometer. This comprises an inflatable (*Riva-Rocci*) cuff placed around the upper arm at roughly the same vertical height as the heart, attached to a mercury or aneroid manometer. The mercury manometer, considered the gold standard, measures the height of a column of mercury, giving an absolute result without need for calibration and, consequently, not subject to the errors and drift of calibration which affect other methods. The use of zmercury manometers is often required in clinical trials and for the clinical measurement of hypertension in high-risk patients, such as pregnant women.

A cuff of appropriate size is fitted smoothly and also snugly, then inflated manually by repeatedly squeezing a rubber bulb until the artery is completely occluded. Listening with the stethoscope to the brachial artery at the antecubital area of the elbow, the examiner slowly releases the pressure in the cuff. When blood just starts to flow in the artery, the turbulent flow creates a "whooshing" or pounding (first Korotkoff sound). The pressure at which this sound is first heard is the systolic blood pressure. The cuff pressure is further released until no sound can be heard (fifth Korotkoff sound), at the diastolic arterial pressure.
The auscultatory method is the predominant method of clinical measurement.