Cardiovascular physiology

Lect.11

Cardiovascular physiology

Cardiovascular system (CVS) consists of:

- Heart
- Blood vessels

Functions Cardiovascular system:

I - primary main functions of the heart:

- Acts as a muscular pump:

In order to maintain adequate level of blood flow throughout CVS by pumping blood under pressure into vascular system.

- responsible for the mass movement of fluid in body.

Functions Cardiovascular system:

II -Secondary functions:

I – Transportation:

- delivers O2 to tissues & brings back CO2 to lungs.
- carries absorbed digestion products to liver & tissues.
- Carries metabolic wastes to kidneys to be excreted.
- Distribution of body fluid.

2-Regulation:

- Hormonal: carries hormones to target tissues to produce their effects.
- Immune: carries antibodies, leukocytes(WBC),cytokines& complement to aid body defense mechanism against pathogens.

- Protection: carries platelets & clotting factors to aid protection of body in blood clotting mechanism.
- Temperature: helps in regulation of body temperature by diverting blood to cool or warm the body

Anatomy of the heart

Right Side of the heart
Left side of the heart

Consists of 2 separated pumps that maintain unidirectional flow of blood:

Lt heart pumps oxygenated blood from the lung to the tissues- **Systemic circulation** by the LV to all organ systems to supply nutrients.

Rt heart pumps deoxygenated blood which has returned from the tissues to the lungs- **Pulmonary circulation**(blood pumped from RV through lungs & back to the heart).

Each pump contains 2 chambers: an atrium & a ventricle.

2 Atria:----receive blood returning back to the heart.

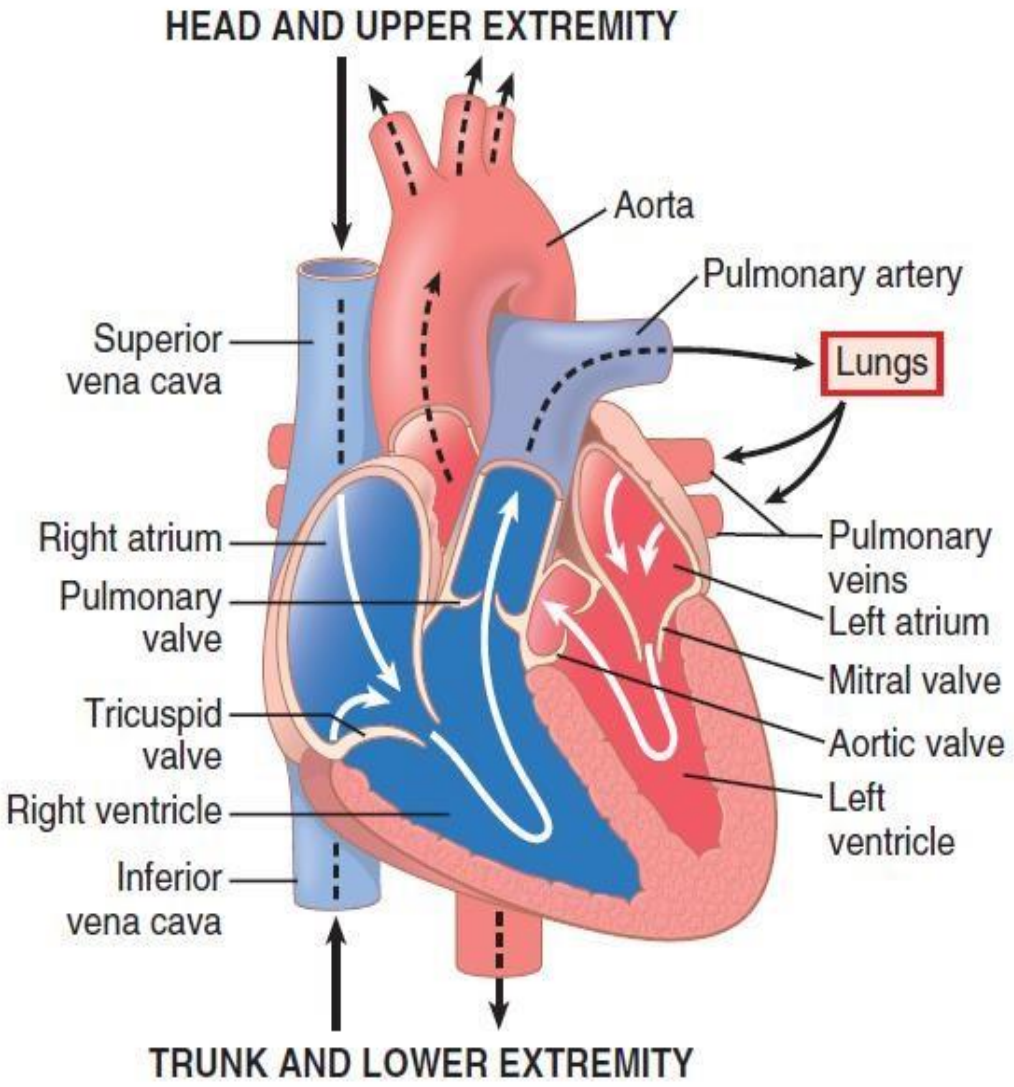
2 Ventricles:-------Pump blood from heart.

Each has same capacity & pumps same volume of blood in a given period of time. Atria & ventricles are separated into 2 functional units by a sheet of fibrous connective tissue, which gives attachment to the valves.

Valves of the heart

are structures which allow the blood to flow in one direction only, they do not contain any muscle tissue. Each ventricle has a valve at its inlet & at its outlet:

- ✓ The inlet valves are termed= 2 atrioventricular (AV)valves, allow blood to flow from atria into ventricles.
- on the left side it is known as the Mitral valve.
- On right side it is known as the Tricuspid valve.
- ✓ The outlet valves are known as = the Semilunar valves



At origin of pulmonary artery & aorta. ▪ The valve on left side of the heart is known as aortic valve ▪ on the right side it is also known as pulmonary valve.

Layers of Wall of the heart

Pericardium: outer covering of the heart. made up of two layers, are separated by a space called pericardial cavity which contains a thin film of fluid.

Myocardium:: middle layer of the wall of heart, formed by cardiac muscle fibers. responsible for the pumping action of the heart. formed by3 types of cardiac muscle fibers:

i. **muscle Fibers which Form the Contractile Unit of the Heart:**
ii. Muscle Fibers which Form the Pacemaker iii. iii. Muscle Fibers which Form the Conductive System

The sarcomere of cardiac muscle has muscle proteins namely, actin, myosin, troponin & tropomyosin.

The important difference between skeletal muscle & cardiac muscle is that the cardiac muscle fiber is branched .

ENDOCARDIUM

is the inner layer of heart wall. is a thin, smooth and glistening membrane. Formed by a single layer of endothelial cells lining the inner surface of the heart- continues as endothelium of the blood vessels.

Cardiac Muscle Is a Syncytium

Intercalated disk

is a tough double membranous structure situated at the junction between the branches of neighboring cardiac muscle fibers.- form adherens junctions which play an important role in contraction of the muscle as a single unit .

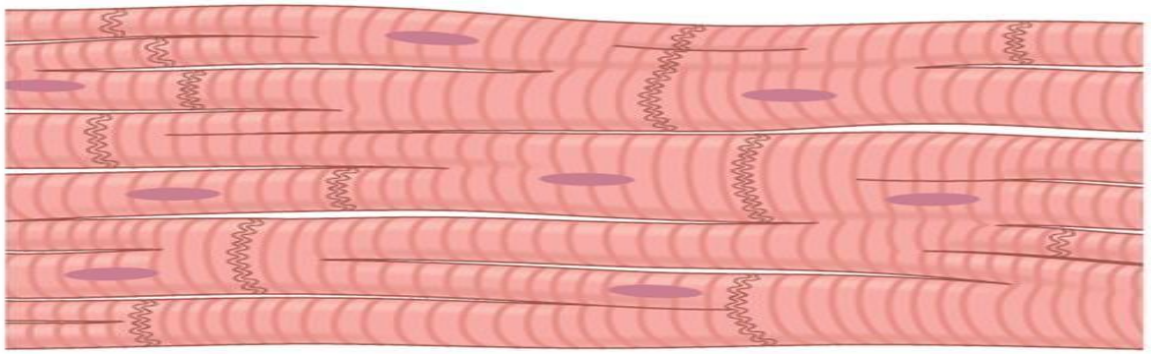


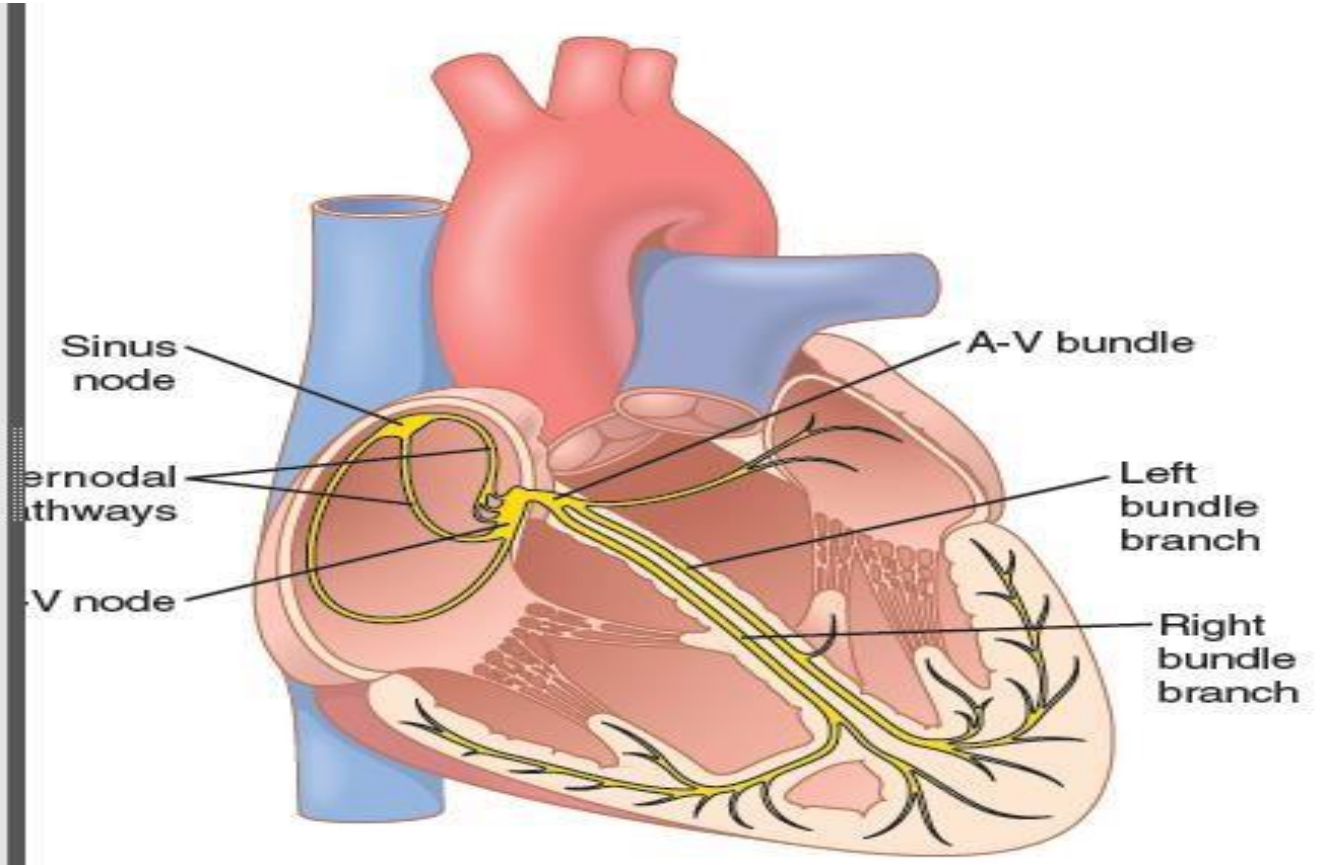
Figure 9-2. Syncytial, interconnecting nature of cardiac muscle fibers.

The structure of cardiac muscle is considered as a syncytium. the adjacent muscle fibers fuse together to form gap junctions which facilitates the rapid conduction of electrical activity from one fiber to another to form permeable “communicating” junctions (gap junctions) that allow rapid diffusion of ions.

This makes the cardiac muscle fibers act like a single unit referred as physiological syncytium. atrial syncytium, which constitutes the walls of the two atria, and the ventricular syncytium, which constitutes the walls of the two ventricles.

Pacemaker:

is structure in the heart that generates the impulses for heart beat. It is formed by the pacemaker cells called P cells. Sinoatrial(SA) node forms the pacemaker in



ure 10-1. Sinus node and the Purkinje system of the heart, wing also the atrioventricular *(A-V)* node, atrial internodal path- s, and ventricular bundle branches.

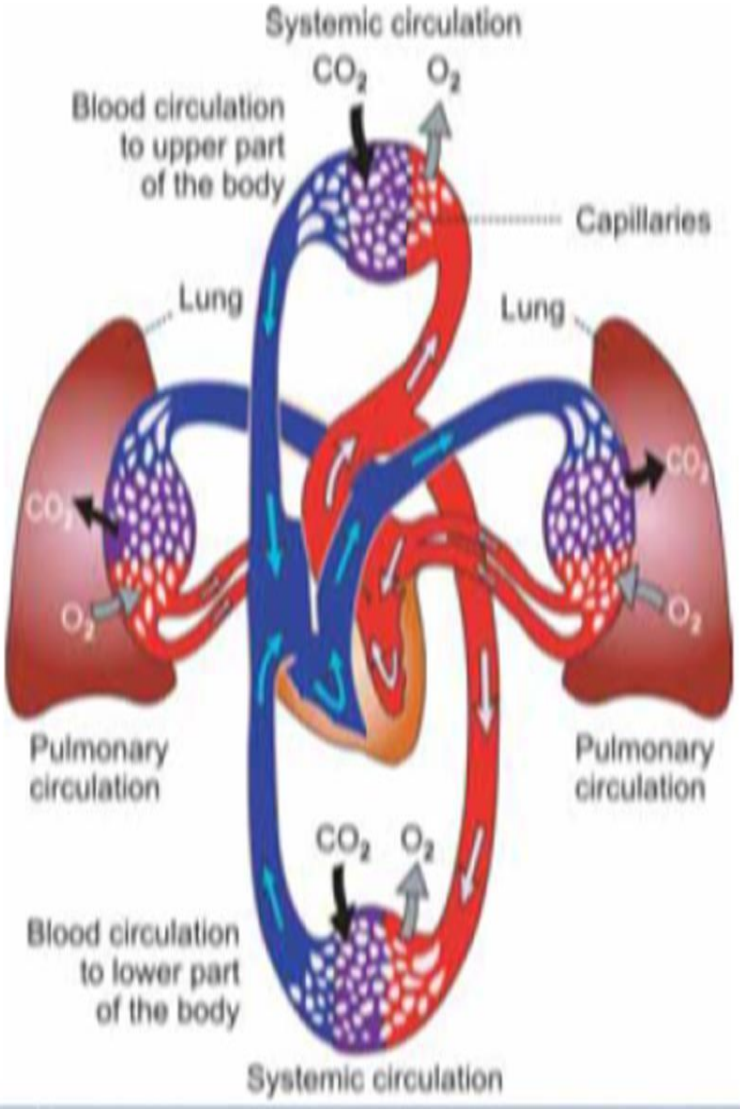
human heart. Though the SA node is the pacemaker in mammalian heart. The muscle fibers forming pacemaker have less striation.

BLOOD VESSELS

Arterial System: comprises the aorta, arteries & arterioles.The arterioles are continued as capillaries

Arteries include the right & left coronary arteries, marginal arteries, anterior & posterior interventricular arteries, & the circumflex artery.

Venous system-From the capillaries starts and it includes the venules, veins and vena cavae. The venules are smaller vessels with thin muscular wall than the arterioles.



Rate of blood flow through systemic circulation = flow rate through pulmonary circulation.

Properties of Cardiac Muscle--
Physiology of cardiac muscle:

✓ EXCITABILITY

is the ability of a living tissue to give response to a stimulus. In all the tissues, the initial response to a stimulus is the electrical activity in the form of action potential. It is followed by mechanical activity in the form of contraction, secretion

✓ RHYTHMICITY

is the ability of a tissue to produce its own impulses regularly--named as autorhythmicity- also called self excitation.

The property of rhythmicity is present in all the tissues of heart. Heart has a specialized excitatory structure from which the discharge of impulses is rapid. This called pacemaker. From this, the impulses spread to other parts through the specialized conductive system.

✓ Contractility –

ability of the tissue to shorten in length (contraction) after receiving a stimulus.
Various factors affect the contractile properties of cardiac muscle.

The contractile properties are:

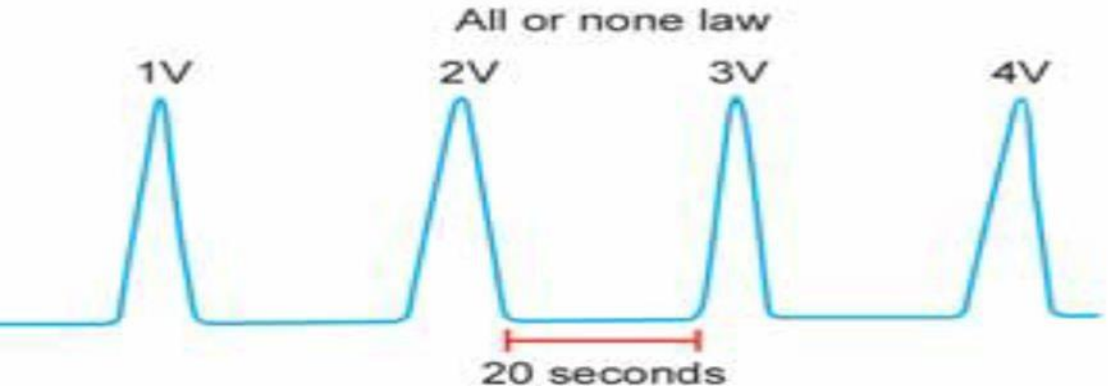
- ❑ **ALL OR NONE LAW**
- ❑ **STAIRCASE PHENOMENON**
- ❑ **SUMMATION OF SUBLIMINAL STIMULI**
- ❑ **REFRACTORY PERIOD**

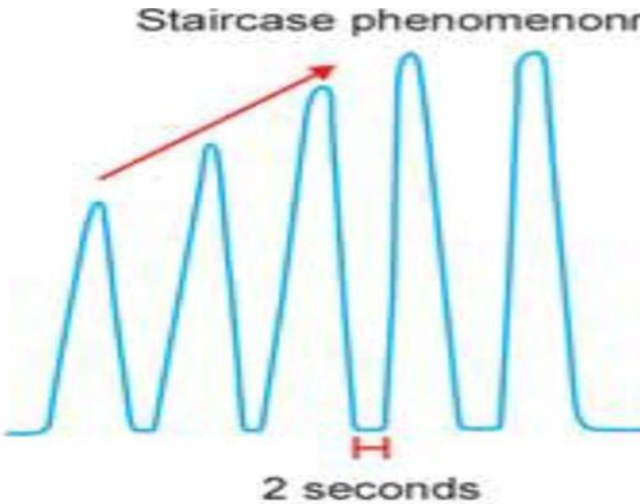
is the period in which the muscle does not show any response to a stimulus. types:

1. Absolute refractory period

is the period during which the muscle does not show any response at all, whatever may be the strength of the stimulus. 2. Relative Refractory Period

is the period during which the muscle shows response if the strength of stimulus is increased to maximum. It is the stage at which the muscle is in repolarizing state.





CONDUCTIVITY

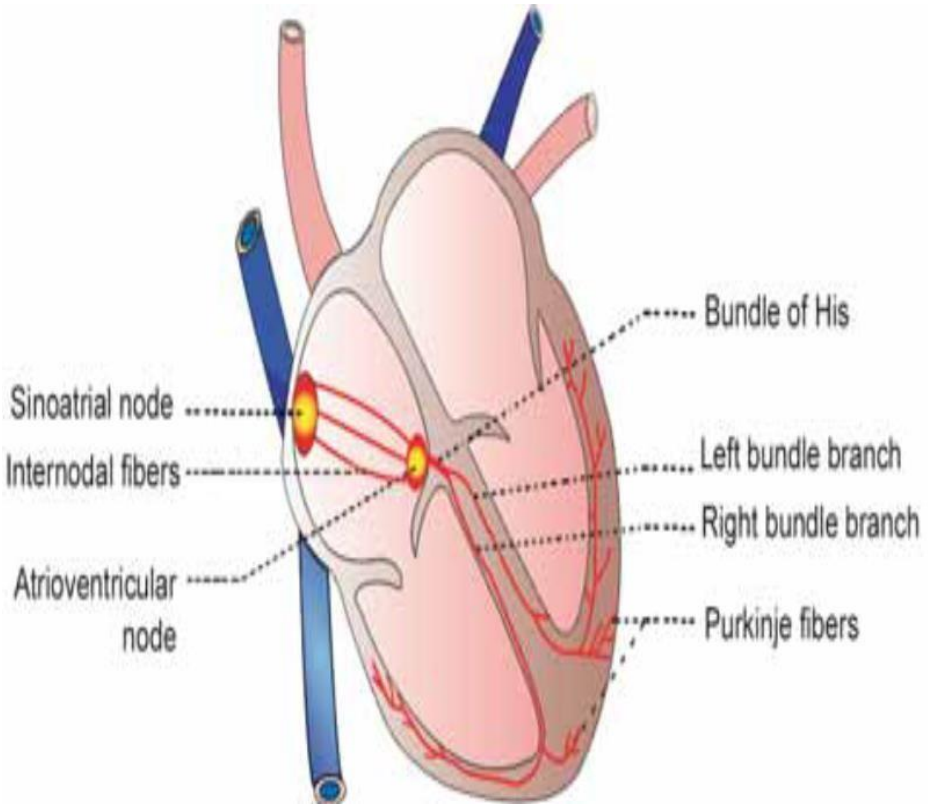
Human heart has a specialized conductive system through which the impulses from SA node are transmitted to all other parts of the heart

CONDUCTIVE SYSTEM IN HUMAN HEART

formed by modified cardiac muscle fibers, also called the junctional tissues. The conductive system in human heart comprises: -- SA node begins the action potential Stimulus spreads to the AV node directly. The impulses also reach AV node via some specialized fibers called intermodal fibers. -- AV node

-- Bundle of His

-- Right and left bundle branches -- Purkinje fibers.



From AV node, the bundle of His arises- divides into right & left bundle branches which run on either side of the interventricular septum. From each branch of Bundle of His many Purkinje fibers arise and spread all over the ventricular myocardium.

Action Potential & IONIC BASIS OF ACTION POTENTIAL

Action potential in a single cardiac muscle fiber occurs in 4 phases:

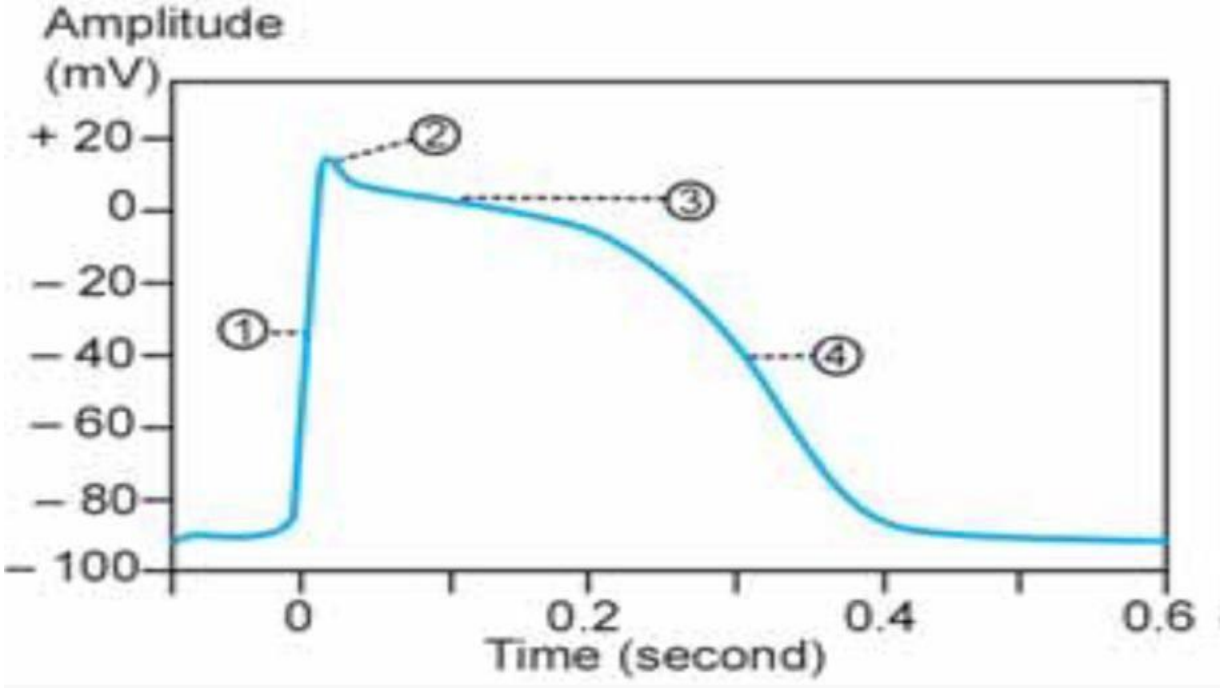
1. Initial depolarization

depolarization- due to opening of fast sodium channels and the rapid influx of sodium ions as in the case of skeletal muscle fiber. When the cardiac cell is stimulated and depolarizes, the membrane potential becomes more positive.

2. Initial repolarization

there is an initial rapid repolarization for a short period of about 2 msec. The end of rapid repolarization is represented by a notch.

is due to the transient (short duration) opening of potassium channels and efflux of a small quantity of potassium ions from the muscle fiber. Simultaneously, the fast sodium channels close suddenly and slow sodium channels open resulting in slow influx of a low quantity of sodium ions.



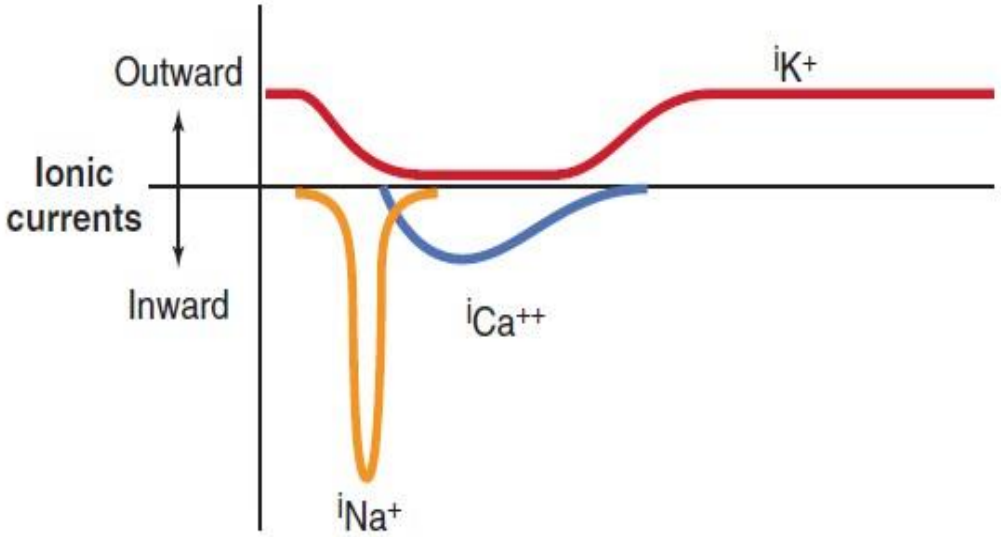


Figure 9-4. Phases of action potential of cardiac ventricular muscle cell and associated ionic currents for sodium (*$^{i}Na^{+}$*), calcium (*$^{i}Ca^{++}$*), and potassium (*$^{i}K^{+}$*).

3. Plateau – Final Depolarization

(stable period) in the action potential curve., the muscle fiber remains in the depolarized state for sometime before further repolarization It forms the plateau.

Due to the long plateau in action potential, the contraction time is longer in cardiac M, by about 5 - 15 times than in skeletal M.

Plateau (final depolarization) is because of opening of calcium channels- are kept opened for a longer period & cause influx of large number of calcium ions. entry of both calcium and sodium ions is responsible for prolonged depolarization.

4. Final Repolarization

Occurs due to increase in efflux of potassium ions increases.

Approximate duration of action potential in cardiac muscle is 250 to 350 msec (0.25 to 0.35 sec).

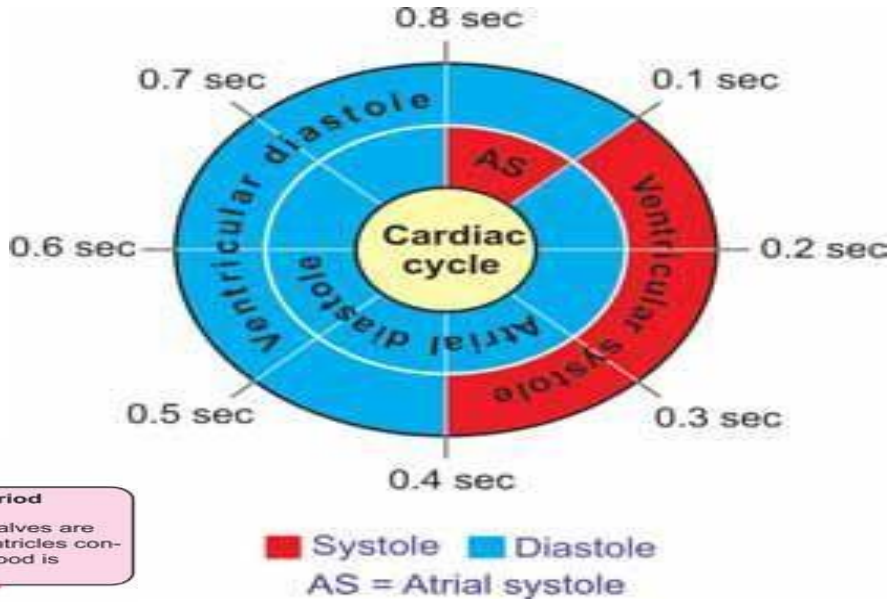
SPREAD OF ACTION POTENTIAL THROUGH CARDIAC M.

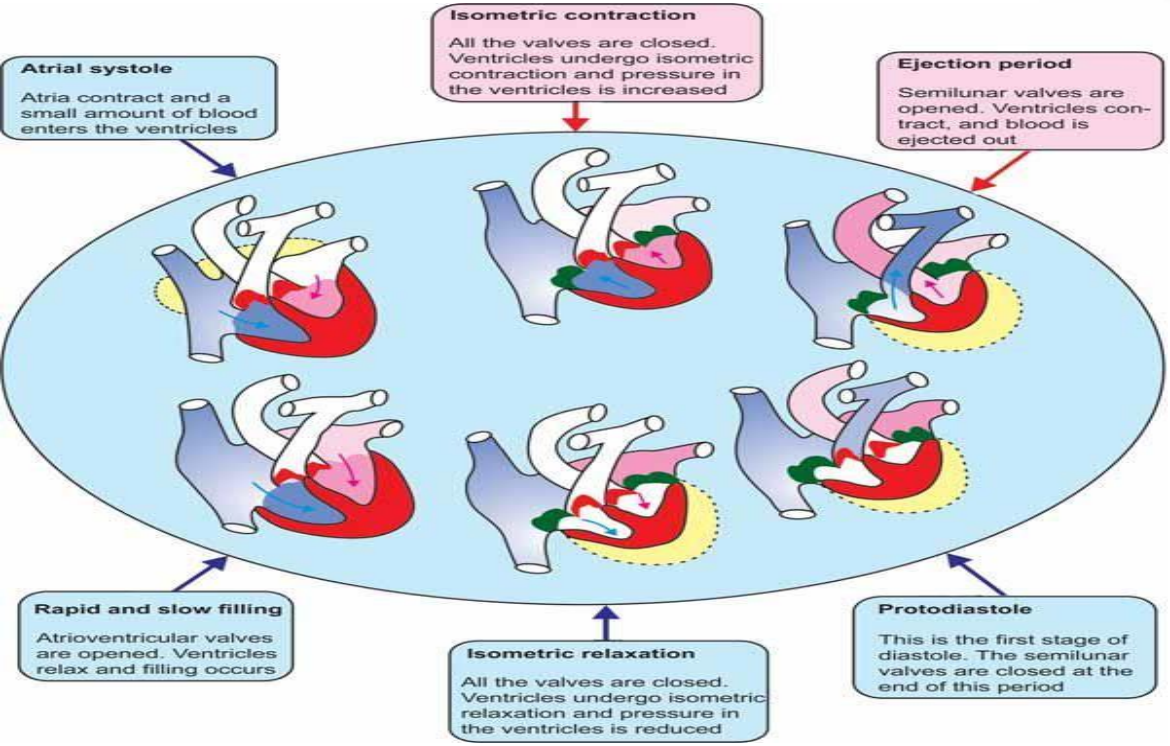
The action potential spreads through the cardiac muscle very rapidly- because of the presence of gap junctions between the cardiac muscle fibers. The gap junctions are permeable junctions and allow free movement of ions. Due to this, the action potential spreads rapidly from one muscle fiber to another fiber.

The action potential is transmitted from atria to ventricles through the fibers of specialized conductive system.

CARDIAC CYCLE

The cardiac events that occur from the beginning of one heartbeat to the beginning of the next are called the cardiac cycle. Each cycle is initiated by spontaneous generation of an action potential in the sinus node,





Heart sounds

are the sounds produced by mechanical activities of heart during each cardiac cycle. Generally, heart sounds are produced by:

1. Flow of blood through the chambers of the heart
2. Contraction of cardiac muscle 3. Closure of valves of the heart.

Four heart sounds are produced during each cardiac cycle

The first & second heart sounds= called classical heart sounds, are heard by using the stethoscope.

The first heart sound is a long, soft & low pitched sound. It resembles the spoken word „LUBB". The duration of this sound is 0.10 to 0.17 second. Its frequency is 25 to 45 cycles/second.

The second heart sound

is a short, sharp and high pitched sound. It resembles the spoken word „DUBB" (or DUP). The duration of the second heart sound is 0.10 to 0.14 seconds. Its frequency is 50 cycles/second

THIRD HEART SOUND

is a short & low pitched. Usually, is inaudible by stethoscope and it can be heard only by using microphone.

The duration of this sound is 0.07 to 0.10 second. Its frequency is 1 to 6 cycles/second.

Third heart sound can be heard by stethoscope in **children and athletes** (Physiological).

- Pathological conditions when third heart sound becomes loud & audible by stethoscope are :

- **aortic regurgitation**
- **cardiac failure**
- **cardiomyopathy with dilated ventricles.**

When third heart sound is heard by stethoscope the condition is called triple heart sound.

FOURTH HEART SOUND

Normally is an inaudible sound, audible only in pathological conditions. It is studied only by graphical recording that is by phonocardiography.

is a short and low pitched sound. The duration of this sound is 0.02 to 0.04 second. And its frequency is 1 to 4 cycles/second.

pathological conditions-Ventricular stiffness occurs in conditions like ventricular hypertrophy, long standing hypertension & aortic stenosis. To overcome the ventricular stiffness, the atria contract forcefully producing audible fourth heart sound.

METHODS OF STUDY OF HEART SOUNDS

1. By using stethoscope
2. By using microphone 3. By phonocardiogram.

CARDIAC MURMUR

is the abnormal or unusual heart sound heard by stethoscope along with normal heart sounds-- also called abnormal heart sound or cardiac bruit.

is produced because of the change in the pattern of blood flow. is heard by placing the chest piece of the stethoscope over the auscultatory areas--due to disease of a particular valve is heard well over the auscultatory area of that valve.

Sometimes, the murmur is felt by palpation as “thrills”. In some patients, is heard without any aid even at a distance of few feet away from the patient.

Valvular diseases are of two types:

1. Stenosis or narrowing of the heart valve: The blood flows rapidly with turbulence through the narrow orifice of the valve resulting in murmur.

2. Incompetence or weakening of the heart valve: When the valve becomes weak, it cannot close properly. It causes back flow of blood resulting in turbulence. This disease is also called regurgitation or valvular insufficiency.

TABLE 61-1: Heart sounds

Features	First heart sound	Second heart sound	Third heart sound	Fourth heart sound
Occurs during	Isometric contraction period and part of ejection period	Protodiastole and part of isometric relaxation	Rapid filling phase	Atrial systole
Cause	Closure of atrioventricular valves	Closure of semilunar valves	Rushing of blood into ventricle	Contraction of atrial musculature
Characteristics	Long, soft and low pitched. Resembles the word 'LUB'	Short, sharp and high pitched. Resembles the word 'DUB'	Low pitched	Inaudible sound
Duration (sec)	0.10 to 0.17	0.10 to 0.14	0.07 to 0.10	0.02 to 0.04
Frequency (cycles per sec)	25 to 45	50	1 to 6	1 to 4
Relation with ECG	Coincides with peak of R' wave	Precedes or appears 0.09 second after peak of 'T' wave	Between 'T' wave and 'P' wave	Between 'P' wave and 'Q' wave
No. of vibrations in phonocardiogram	9 to 13	4 to 6	1 to 4	1 to 2

Activate Windo
Go to Settings to acti

Cardiac output

is the amount of blood pumped from each ventricle. Usually, refers to the left ventricular output through aorta. is most important factor in cardiovascular system, because, the rate of blood flow through different parts of body depends upon the cardiac output. **cardiac output is expressed in three ways:**

1. STROKE VOLUME

It is the amount of blood pumped out by each ventricle during each beat. Normal value: 70 mL (60 to 80 mL) when the heart rate is normal (72/minute).

2. MINUTE VOLUME

is the amount of blood pumped out by each ventricle in one minute. It is the product of stroke volume and heart rate: Minute volume = Stroke volume × Heart rate Normal value: 5 liters/ ventricle/ minute.

3. CARDIAC INDEX

is the minute volume expressed in relation to square meter of body surface area. It is defined as the amount of blood pumped out per ventricle/minute/ square meter of the body surface area. Normal value: Cardiac index = 2.8 ± 0.3 liters/ square meter of body surface area/ minute.

MEASUREMENT OF CARDIAC OUTPUT

The methods used to measure cardiac output are:

1. By using Fick‟s principle
2. Indicator (dye) dilution technique
3. The rmodilution technique
4. Ultrasonic Doppler transducer technique 5. Doppler echocardiography
6. Ballistocardiography.