



CVS revision

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Introduction



The heart

• Physiological anatomy of the heart:

- Heart: hollow muscular organ.
- Site: in left side of thoracic cavity, partly behind the sternum.
- Size: approximately the size of a **man's fist**.
- Weight: - ♂ 320gm. - ♀ 250gm.
- Heart: is enclosed in a sac called **pericardium**.



• Pericardium:

➤ Formed of two layers:

1. Parietal layer: lines the thoracic cavity.

2. Visceral layer: (epicardium).

➤ Pericardial space

■ Present between the visceral and parietal layers.

■ Contains small amount of fluid → lubrication for the continuous movement of the enclosed heart.



➤ What is the importance of pericardium?

1- prevention of sudden over distension of the heart.

2- It gives support to the heart.

• Layers of the cardiac muscle:

1- Endocardium: the most inner layer.

2- Myocardium: an intermediate thick muscular layer.

3- Epicardium: the most outer layer (visceral pericardium).



• Types of cardiac muscle fibers:

(I) Nodal fibers:

1. Sinoatrial node (SAN):

- Located in: Posterior wall of right atrium, immediately beneath & medial to opening of SVC.

2. Atrioventricular node (AVN)

- Located in: Right side of inter atrial septum at junction of atria and ventricles, close to opening of coronary sinus.

(II) Specialized conducting fibers:

- * AVN → AV bundle → divides into **two branches**
- * It is the only connection between atria and ventricles.

(III) contractile muscle fibers:

A. Atrial muscle (Right and left atria)

B. Ventricular muscle (Right and left ventricles)



A. Atrial muscle (Right and left atria)

■ Functions:

a. Blood reservoirs.

b. Pumping 30% of venous return into ventricles during their diastole. The remaining 70% passes from atria to ventricles ***without pumping.***

- c. Contain SAN & AVN (important for initiation & propagation of action potential).
- d. Contain receptors of many cardiac reflexes.
- e. Secrete atrial natriuretic peptide (ANP) → important in regulating ABP



B. Ventricular muscle (Right and left atria)

- Function: Act as pump which ejects the blood into arteries.



• Cardiac valves:

➤ Types:

(1) Atria ventricular valves (AV valves): (Separate atria from ventricles).

* Tricuspid valve: It communicates RA with RV.

* Mitral valve (left AV valve): It communicates LA with LV

(2) Semilunar valves:

* Aortic valve: it communicate LV with Aorta

* Pulmonary valve: It communicates RV with pulmonary artery



Function of cardiac valves:

(1) *AV valves* prevent backflow of blood from ventricles to atria during ventricular systole.

(2) *Semilunar valves* prevent backflow of blood from aorta and pulmonary arteries to ventricles during ventricular diastole.

(3) Valves allow passage of blood only in one direction inside the heart

MCQ

Which layer of the heart contains the contractile muscle fibers responsible for pumping blood?

- A. Endocardium
- B. Visceral layer of the pericardium
- C. Myocardium
- D. Epicardium
- E. Parietal layer of the pericardium

Answer: C



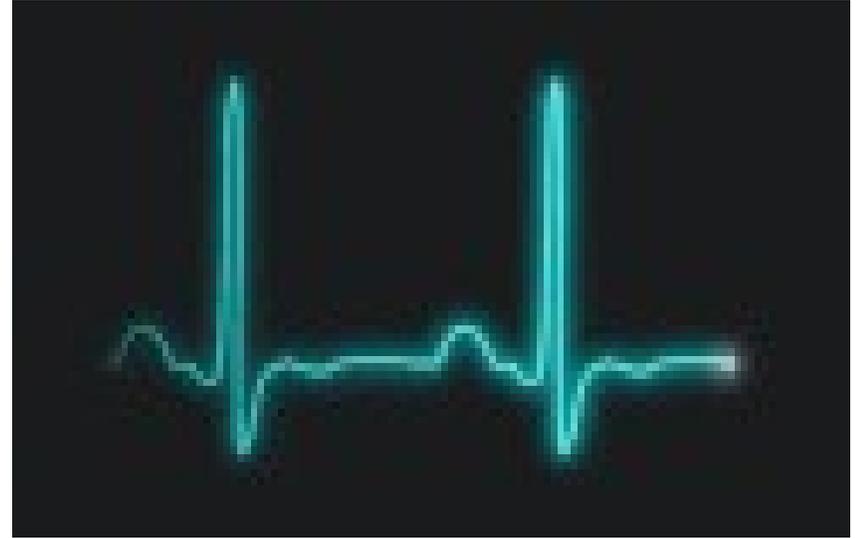
Cardiac properties

Properties Of Cardiac Muscle

- **Rhythmicity**
- **Excitability**
- **Conductivity**
- **Contractility**

Rhythmicity

- ❖ **Definition:** It is the ability of heart to **beat regularly**.
- ❖ **Origin:** **Myogenic** (not neurogenic). The nerves control the rate but do not initiate the beat.
- ❖ **Evidence that rhythmicity is myogenic:**
 - Heart of human fetus start to **beat before development of nerves**.
 - **Transplanted heart** (no nerve supply) continues to **beat**.

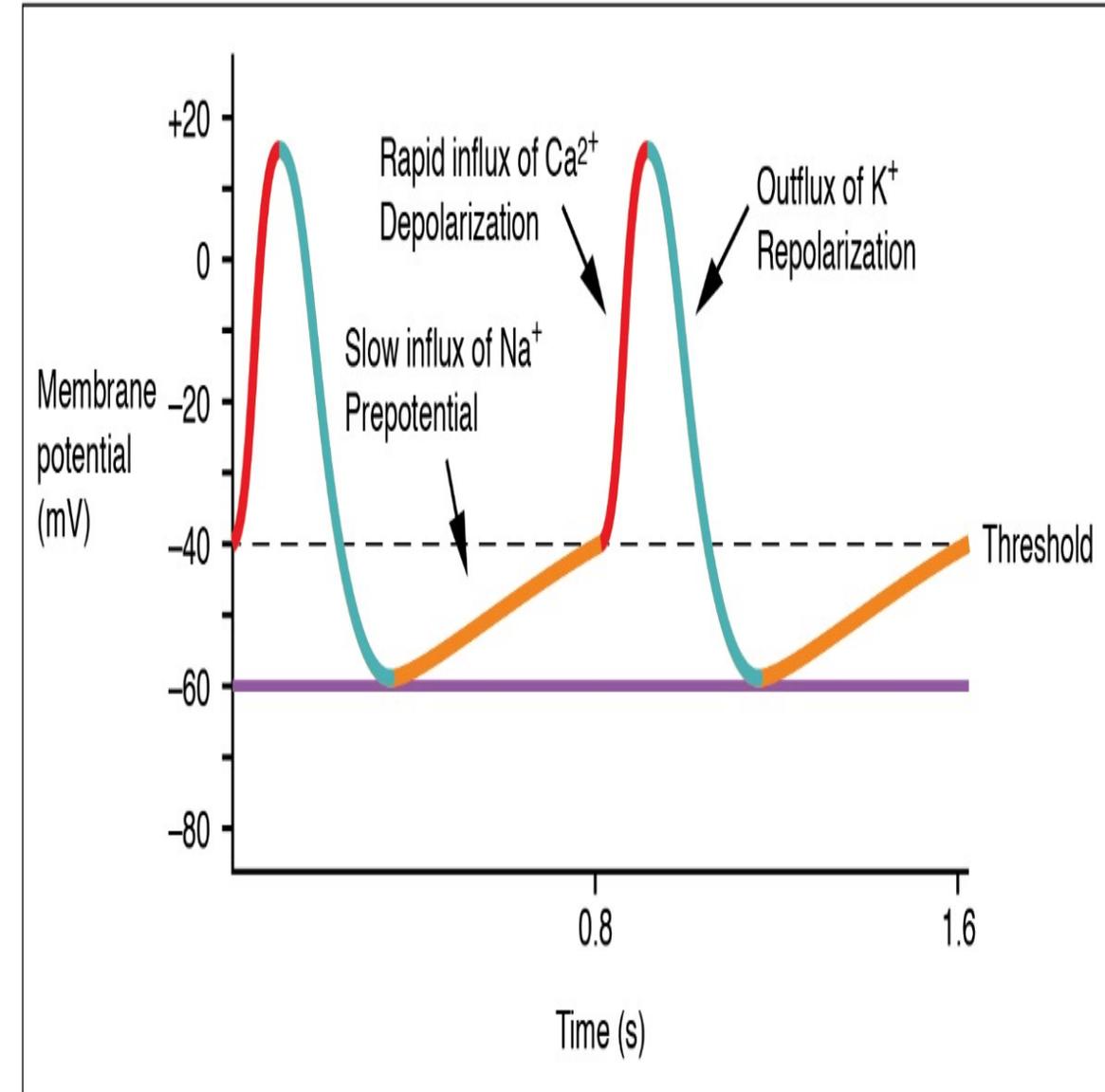


Mechanism of rhythmicity of the SAN (SAN action potential)

The action potential is composed of the 3 phases (403):

1. Pacemaker potential or prepotential (phase 4)

- The membrane potential rises gradually from the resting level of $-55\text{--}60\text{ mV}$ to the firing level of -40 mV .



Mechanism of rhythmicity of the SAN (SAN action potential)

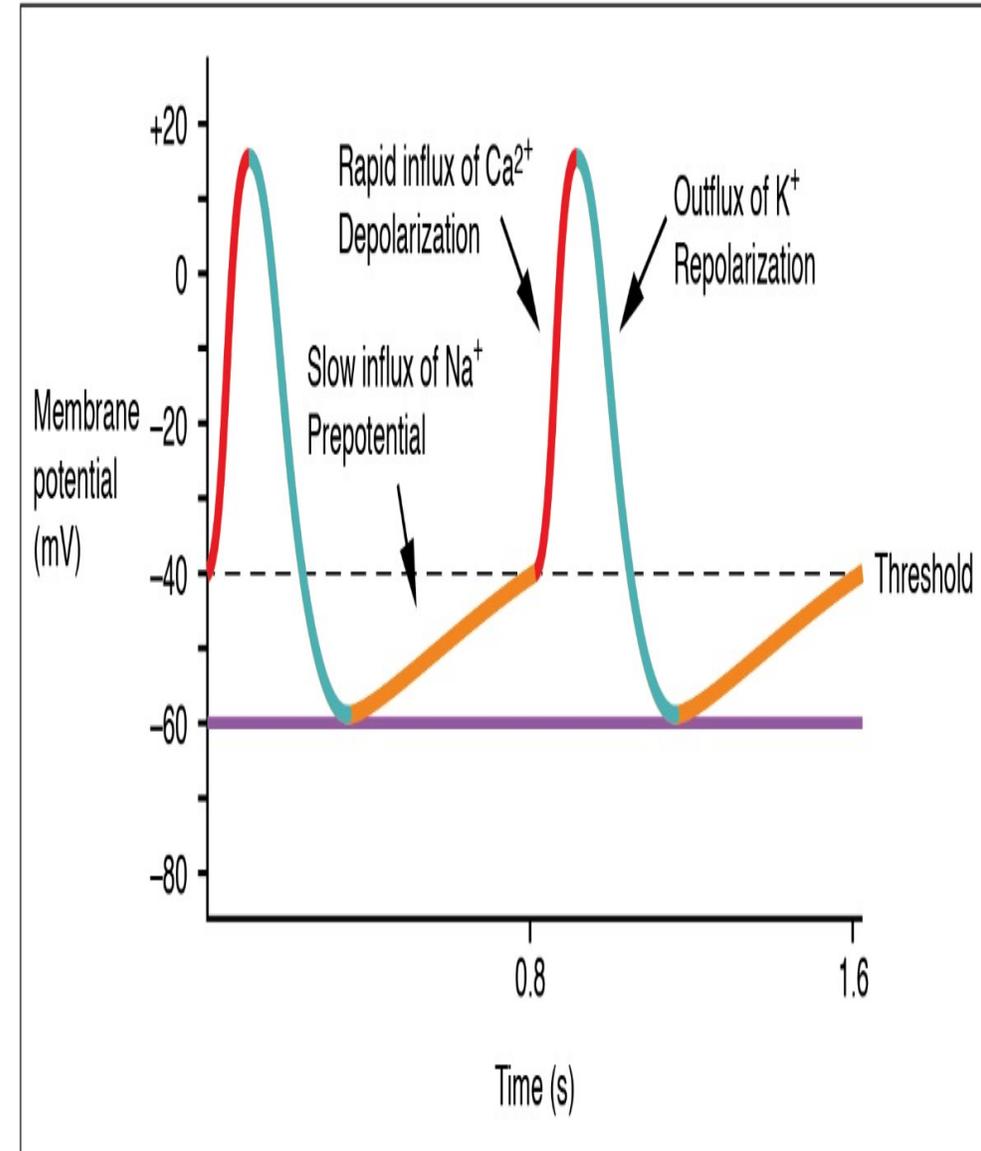
1. Pacemaker potential or prepotential (phase 4)

- **It is due to:**

- A. **Na influx through funny (slow) Na channels**
- B. **Ca influx through T (transient) type Ca channel**
- C. **↓ K⁺ efflux.**

Importance:

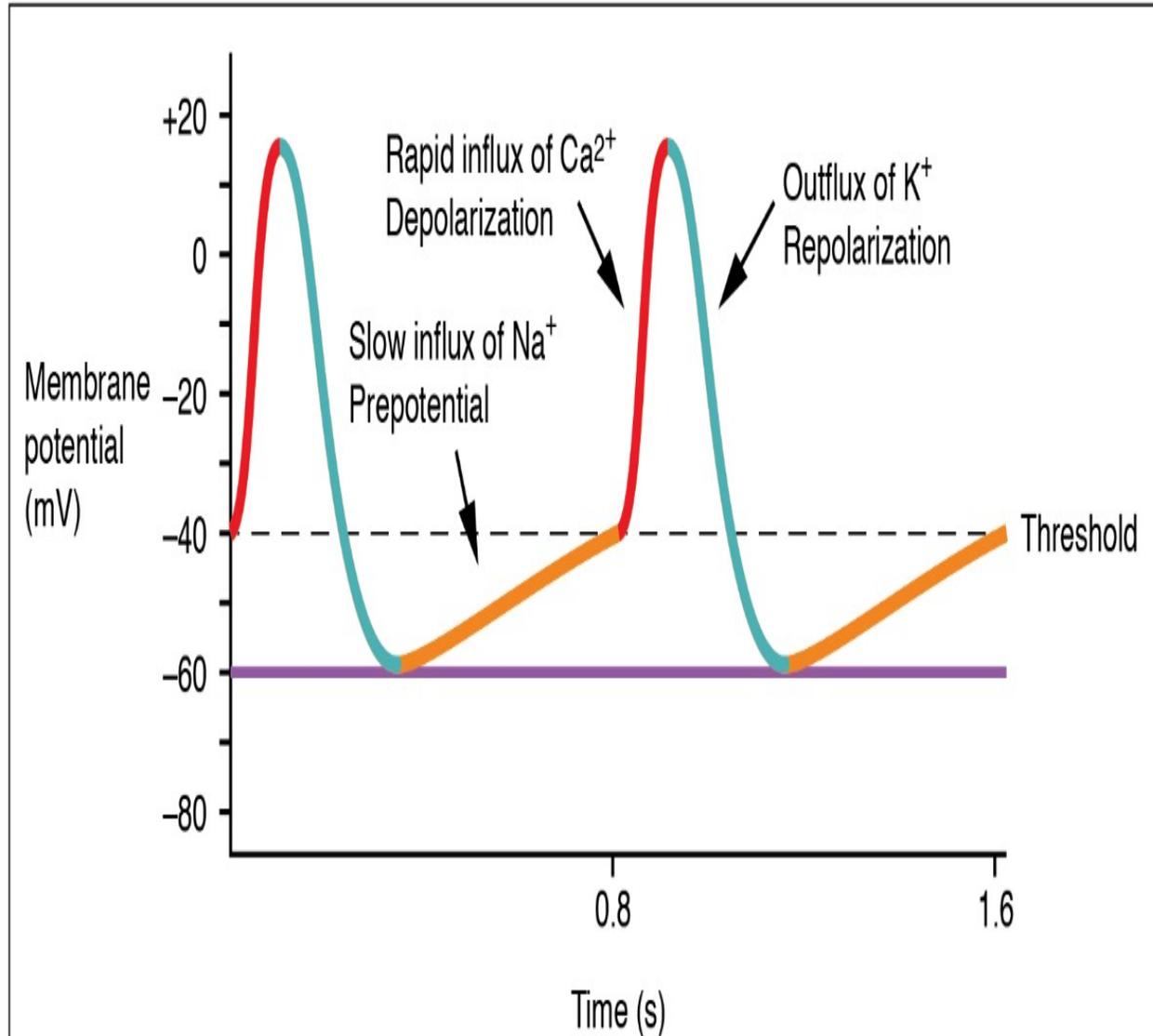
- **It is the cause of rhythmicity.**
- **Rate of slope of prepotential determine the heart rate** (the more rapid slope → the more the heart rate).



Mechanism of rhythmicity of the SAN (SAN action potential)

2. Depolarization (upstroke) phase (phase 0):

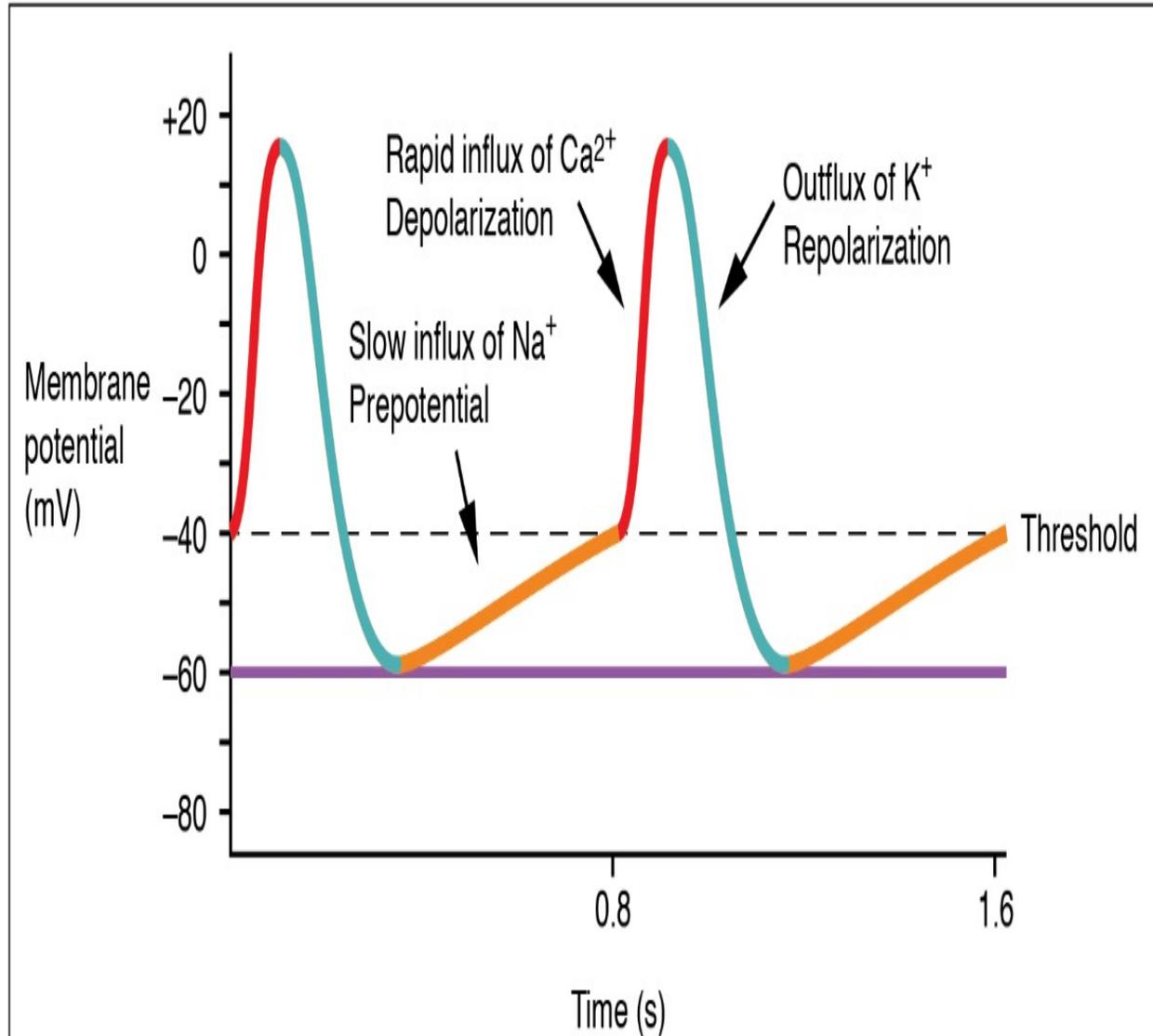
- From membrane potential (-40 mV) to ($+10$ mV).
- Generated by inward Ca current through L (long lasting) Ca channels (Na current is negligible in SA node cells).



Mechanism of rhythmicity of the SAN (SAN action potential)

3. Repolarization (phase 3):

- Occurs due to :
 - **Stoppage of Ca^{++} influx**
 - **increase K^+ efflux**
- which **brings back** the membrane potential to the unstable **RMP (-55 to -60 mv)**
- Then, this process is repeated continuously through life.



Conductivity

*** Definition:** Ability of cardiac muscle to conduct excitation wave from one part to another.

***Normally AP starts from SAN (pacemaker) and is propagated to the rest of the cardiac tissue in the following steps**

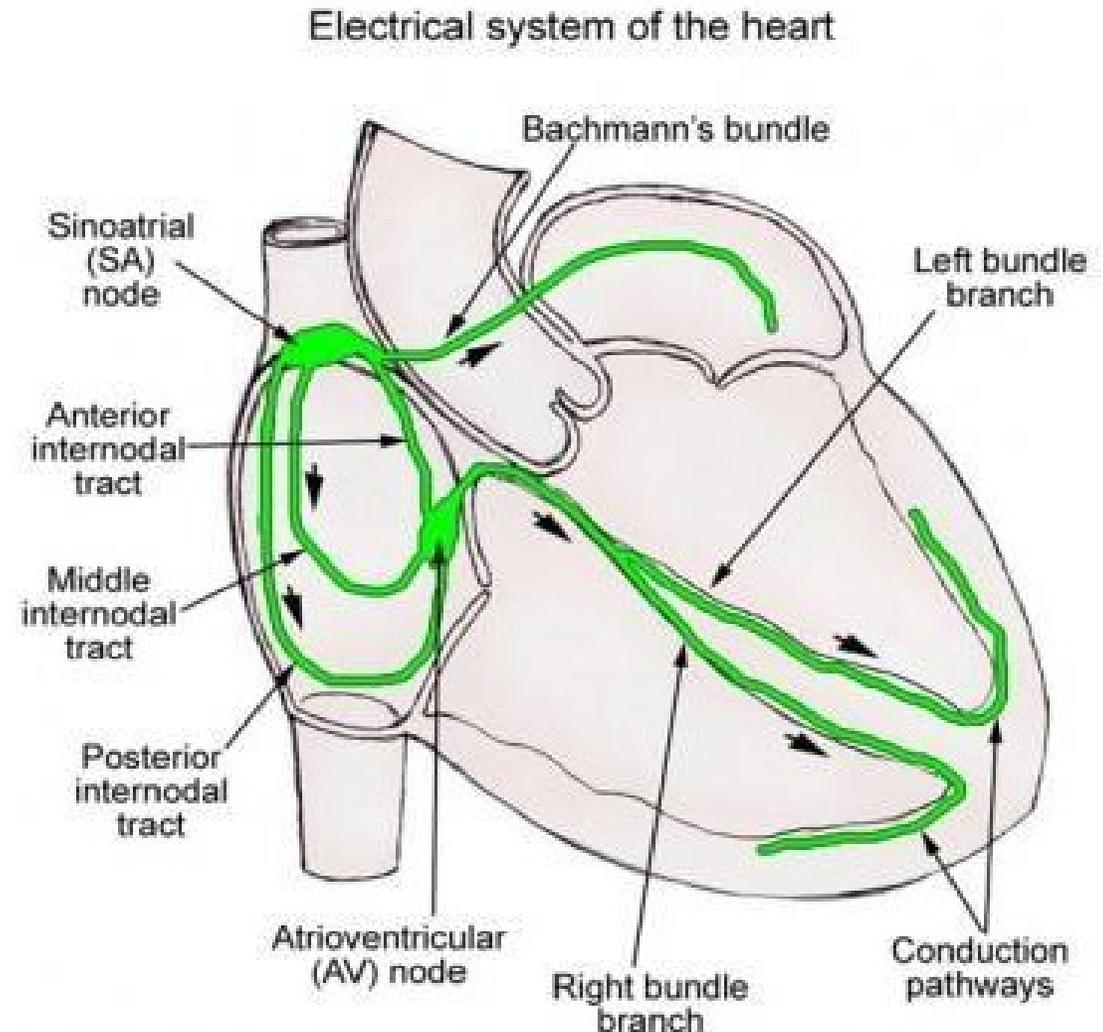
- 1. Transmission of cardiac impulse through atria**
- 2. Transmission of cardiac impulse through AVN (AVN delay)**
- 3. Transmission in Purkinje system**
- 4. Transmission of cardiac impulse in ventricular muscle**

(1)Transmission of cardiac impulse through atria

❖ The action potential is initiated in SAN then travel as follows:

- Right and left atrial mass.
- Anterior interatrial band to left atrium.
- Anterior, middle, and posterior internodal bundles, directly to AVN.

Velocity in atria = 1m/sec.

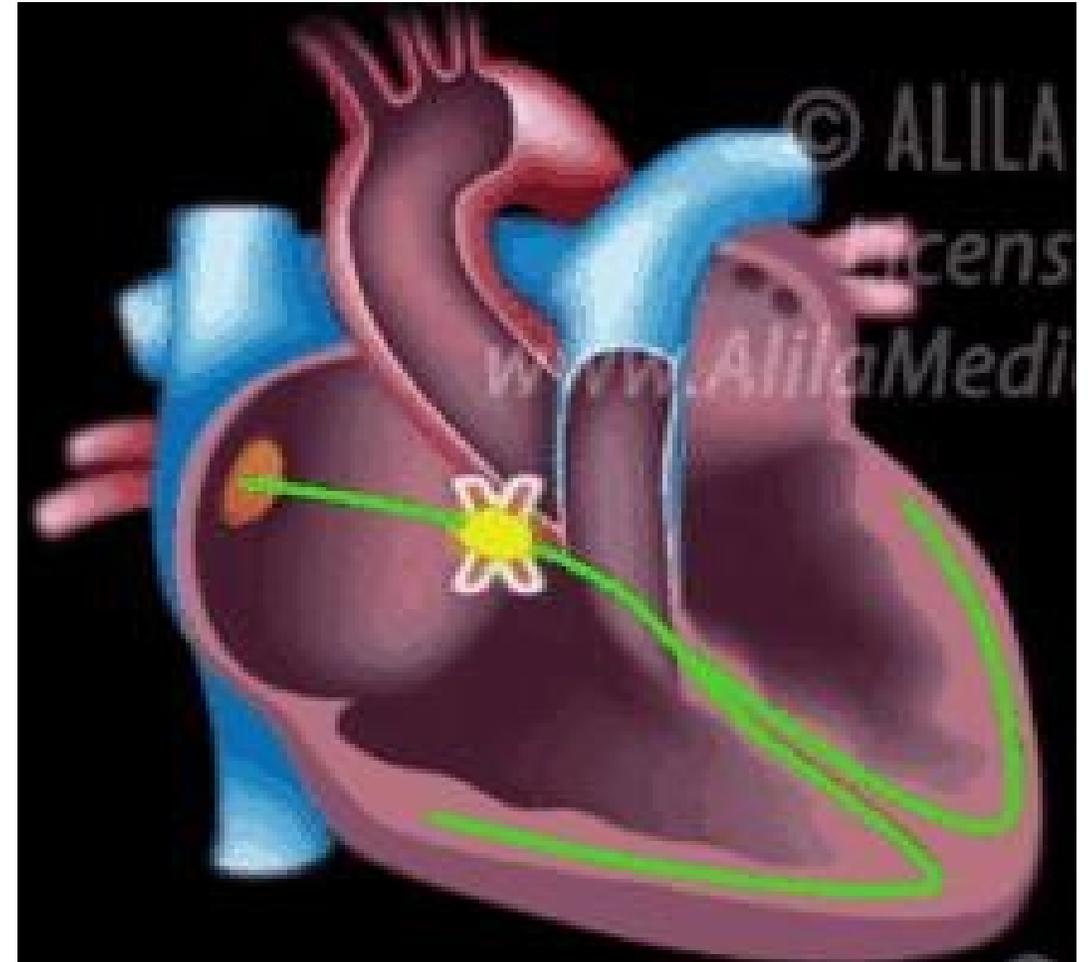


(2) Transmission of cardiac impulse through AVN (AVN delay):

❖ **Velocity : 0.02 – 0.05 m/s.**

❖ **Sites of AVN delay**

Site of delay	sec.
Initial conduction delay between SAN and AVN	0.03
AVN	0.09
Penetrating portion of AVB	0.04
Total delay in the heart	0.16



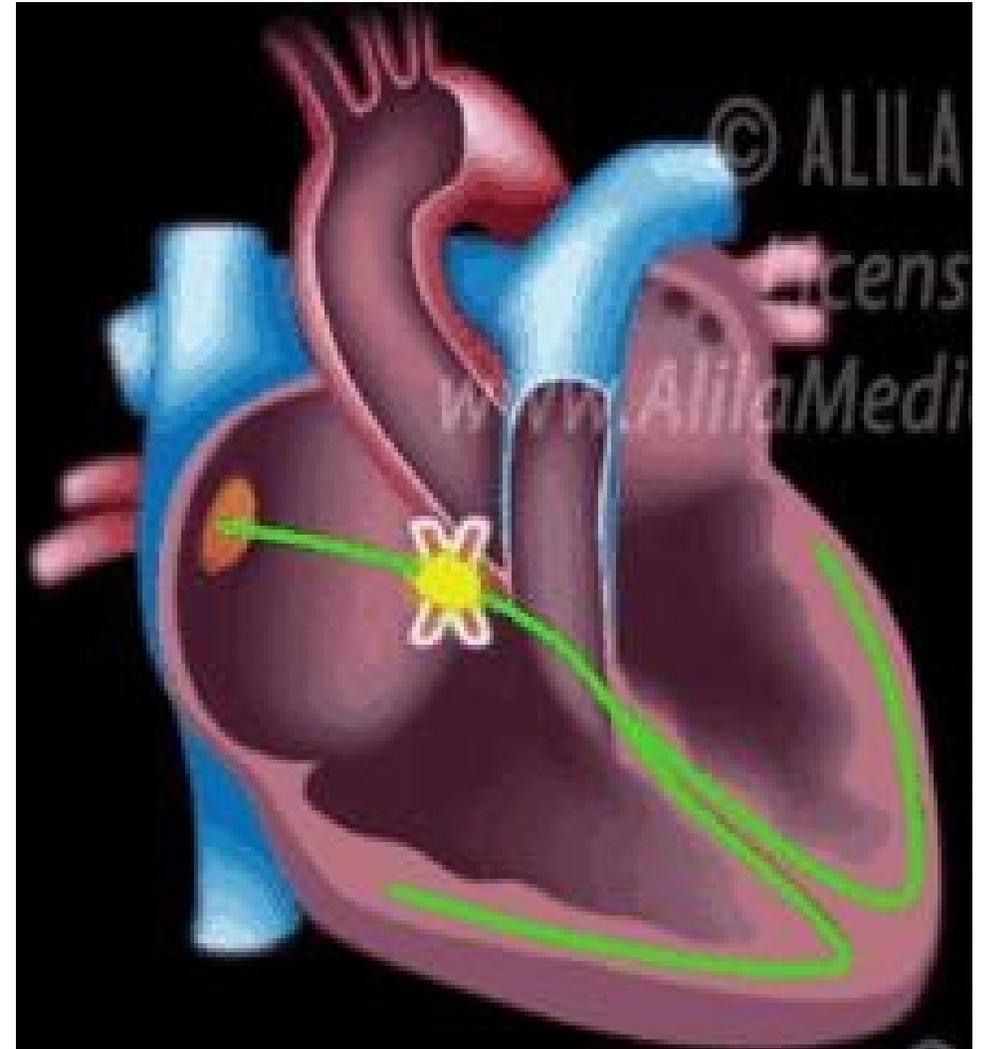
(2) Transmission of cardiac impulse through AVN (AVN delay):

❖ Causes of AVN delay:

1. **Smaller size** of nodal **fibers** than atrial fibers.
2. **Few gap junctions**.

❖ Significance of AVN delay:

1. **Allow sufficient time for atria to empty their blood into ventricle** before ventricular contraction begins.
2. **Protect the ventricle** from pathological high atrial rhythm as AF and atrial flutter.



MCQ

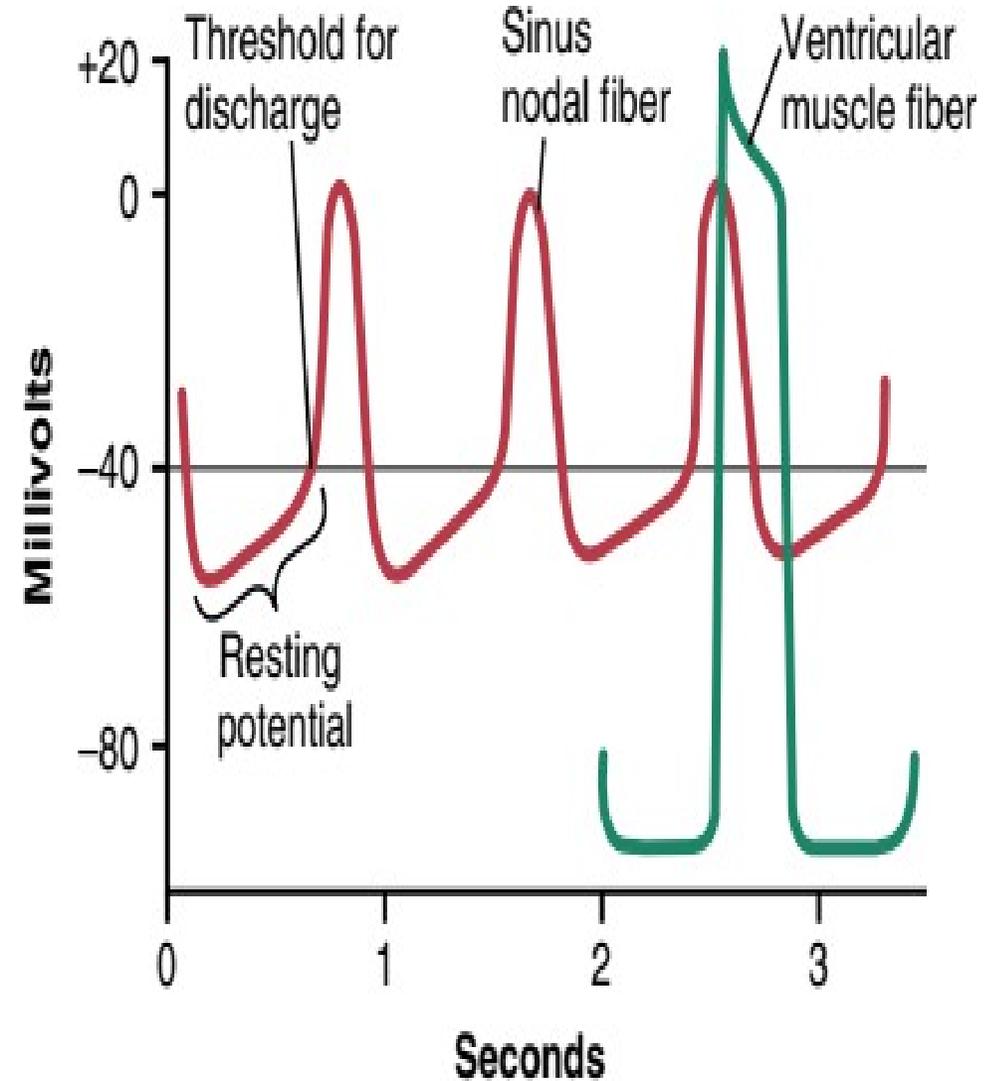
What is the rhythmicity of SA node?

- a) 110 beats / min
- b) 90 beats / min
- c) 45 beats / min
- d) 35 beats / min
- e) 25 beats / min

Answer: a

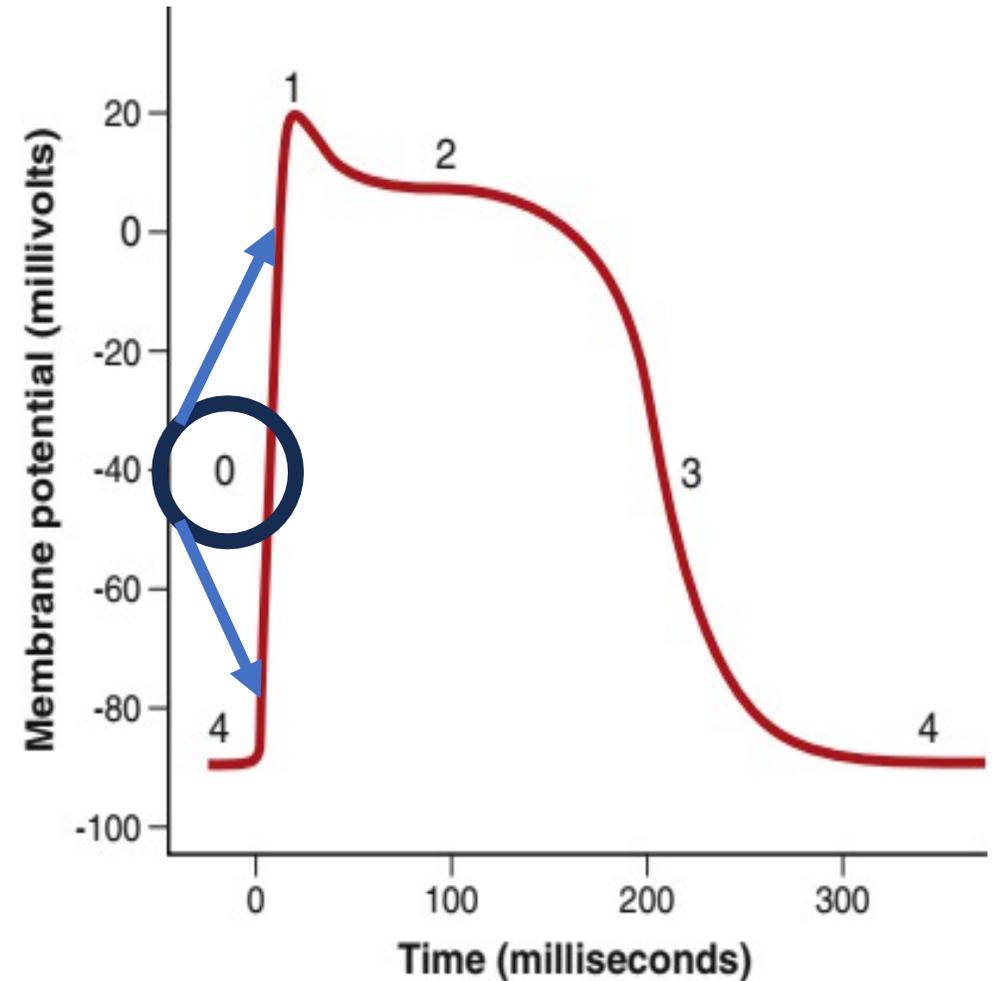
EXCITABILITY

- ❖ **Definition:** It is the ability of the cardiac muscle to **respond to** adequate **stimulus** by generation of action potential followed by mechanical events (Systole & Diastole).
- ❖ On stimulation of a cardiac muscle fiber, a **fast response action potential is generated**; it is composed of **five phases (0,1,2,3,4)**



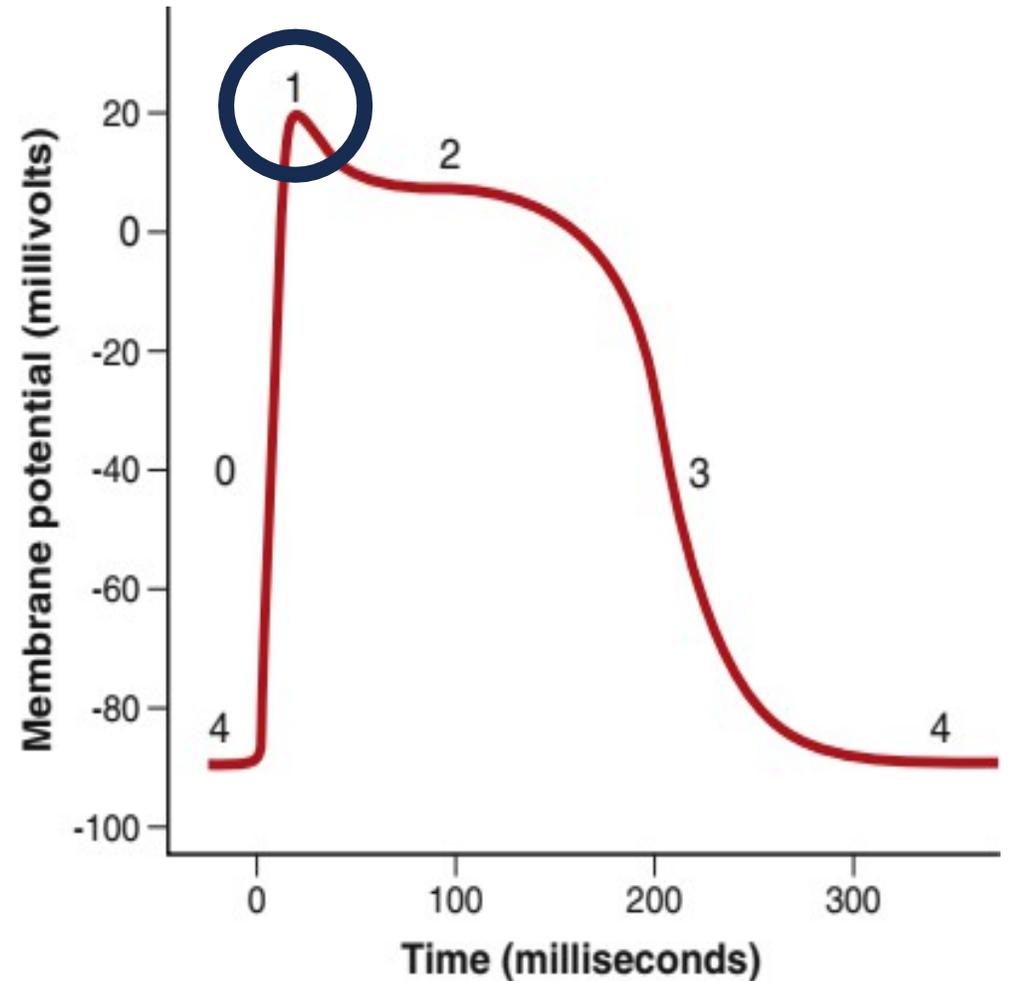
1- Rapid depolarization (Phase 0)

- Membrane potential increase **from -85 to +20mv.** +ve portion is called overshoot potential.
- **Cause: Opening of fast Na⁺ channels** → increase membrane permeability to Na⁺ → **rapid Na⁺ influx.**
- Voltage of A.P → 105 mv.



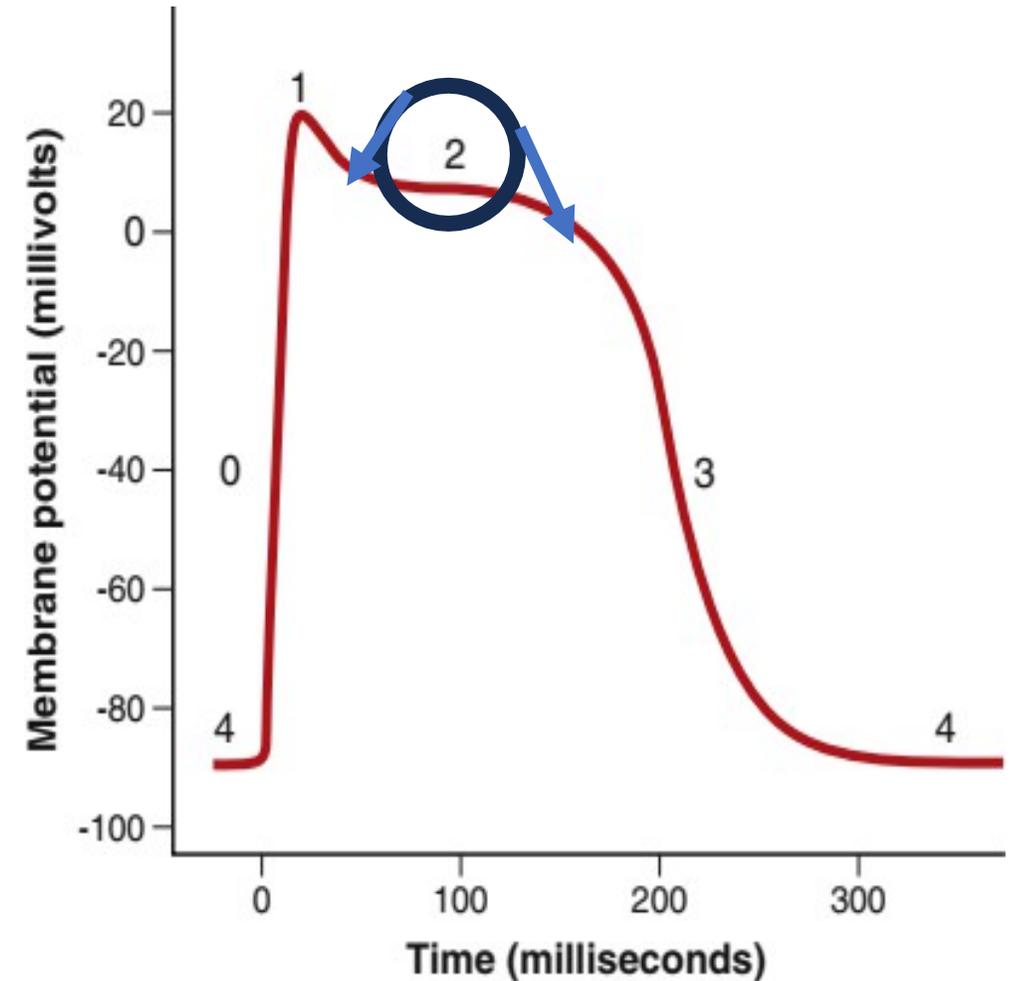
2- Early Partial repolarization (phase 1)

- Small fast repolarization due to:
 - **Limited K⁺ efflux.**
 - **Cl⁻ influx and**
 - **Inactivation of most of fast Na channels.**



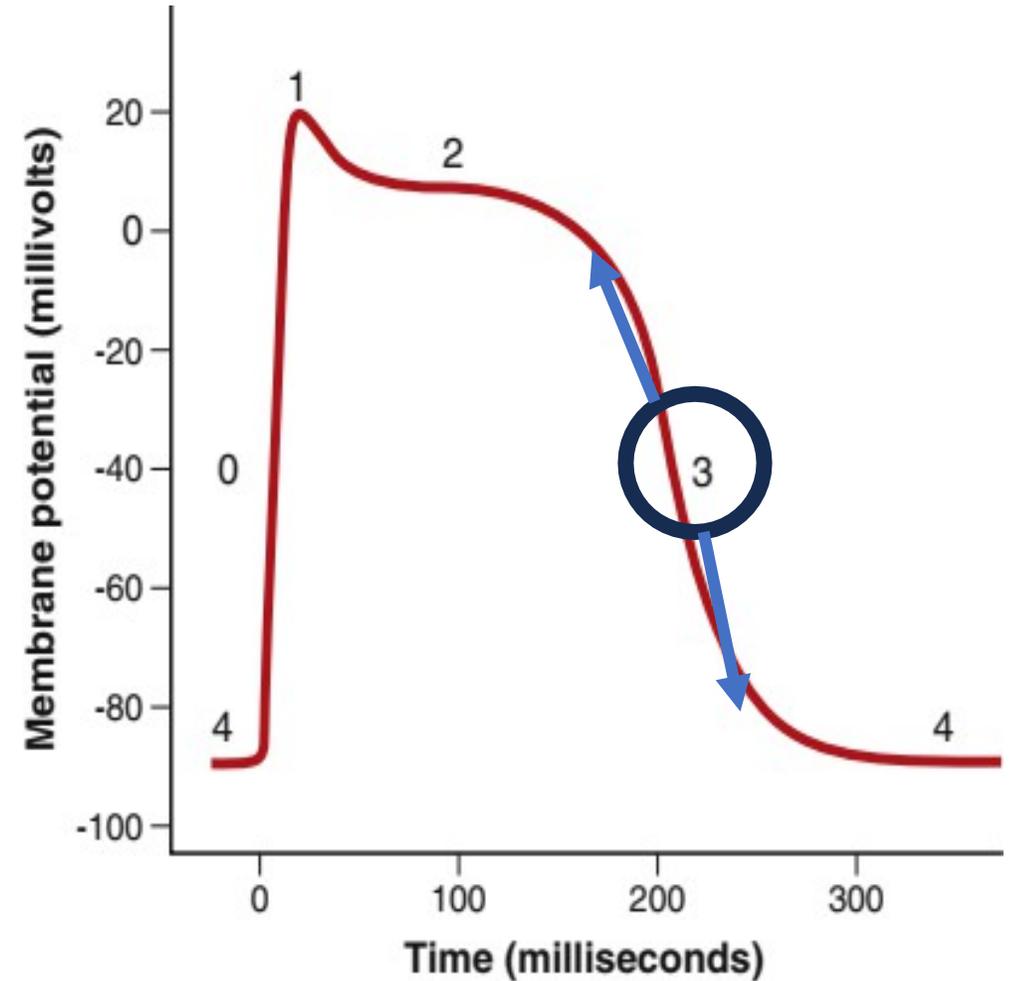
3- Slow prolonged phase (plateau) (phase 2)

- After phase 1 the membrane potential remains depolarized for **0.15** second in **atrial muscles** and **0.3** second in **ventricular muscles** (plateau) due to :
 - **Ca⁺⁺ influx through L-type calcium channels**
 - **Decreased K⁺ efflux and consequently delayed repolarization.**



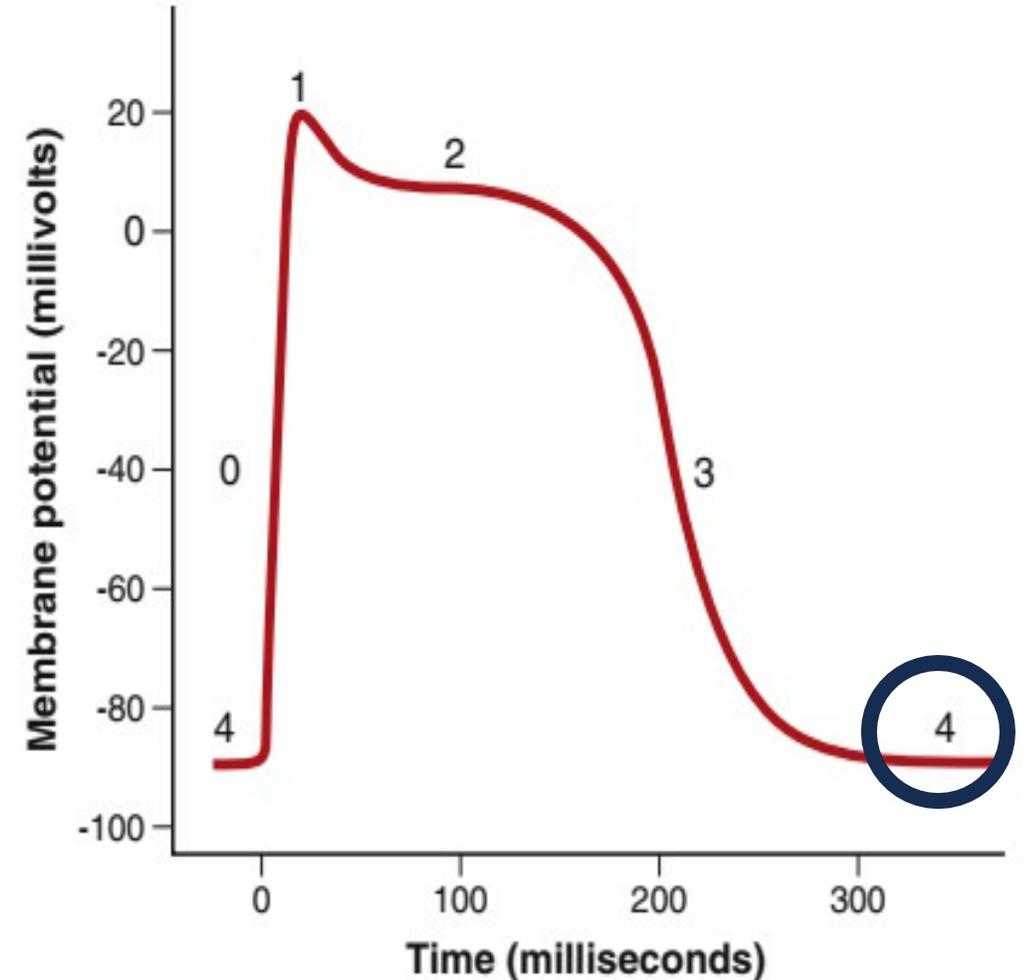
4- Rapid repolarization (phase 3)

- Outward current overcomes inward current due to **marked increase in K efflux** beside **closure of Ca channels**.



5) Complete repolarization (phase 4)

- It occurs when the membrane potential **comes to the resting level.**
- **Na-K pump works** to derive excess Na^+ out and excess K^+ in.
- The resting membrane potential **remains stable till it is excited by the next impulse.**



Contractility

Def: It is the ability of cardiac muscle to **convert** the potential energy (AP) into mechanical energy (**contraction**).

Sources of Ca^{2+} :

- 1. 20% of Ca^{++} from ECF** through opening of L-type calcium channels in muscle cell membrane and down the T tubules.
- 2. 80% of Ca^{++} from S.R** through opening of calcium-sensitive release channels on the SR by local rise of Ca^{++} (**calcium induced calcium release**).

MCQ

What is the effect of sympathetic stimulation on heart?

- a) Increase contraction force of atrium and ventricle
- b) Decrease excitability
- c) Decrease rhythmicity
- d) Decrease conduction velocity
- e) Decrease coronary blood flow

Answer: a



Cardiac cycle

Cardiac cycle

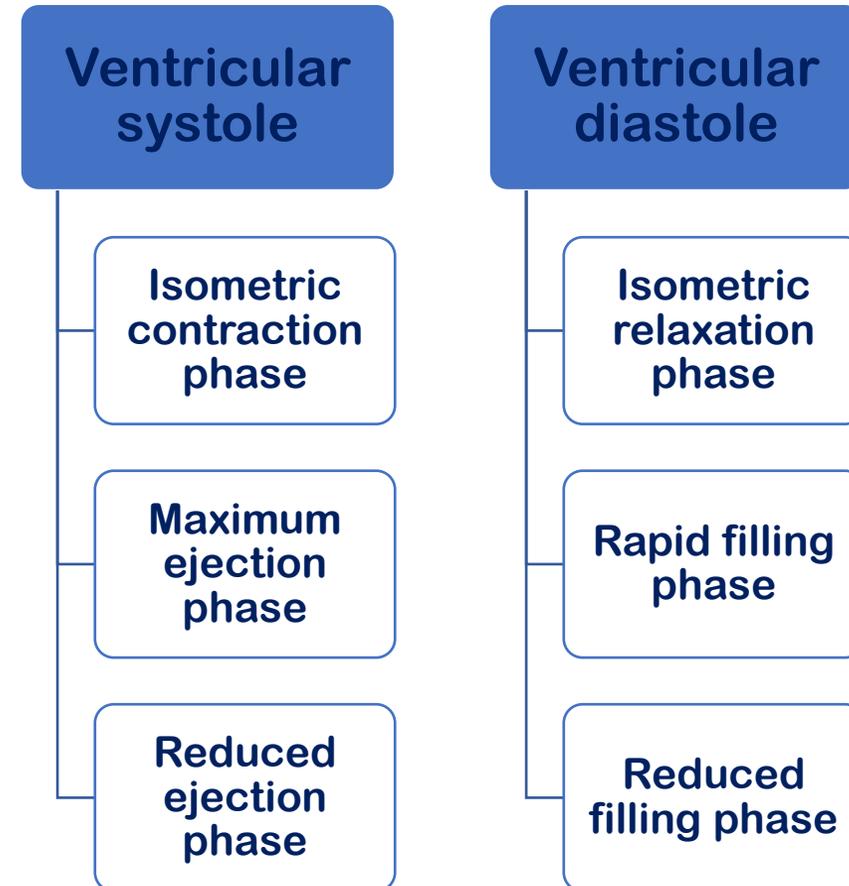
- **Def:** Cardiac events that occur from the beginning of one heart beat to the beginning of the next beat.
- **Consists of:** period of contraction (systole) & period of relaxation (diastole).
- **Duration:** 0.8 second (heart rate: 75/min).

	Systole	Diastole
Atria	0.1 sec	0.7 sec
Ventricle	0.3 sec	0.5 sec
Whole heart	-	0.4 sec

Phases of the cardiac cycle

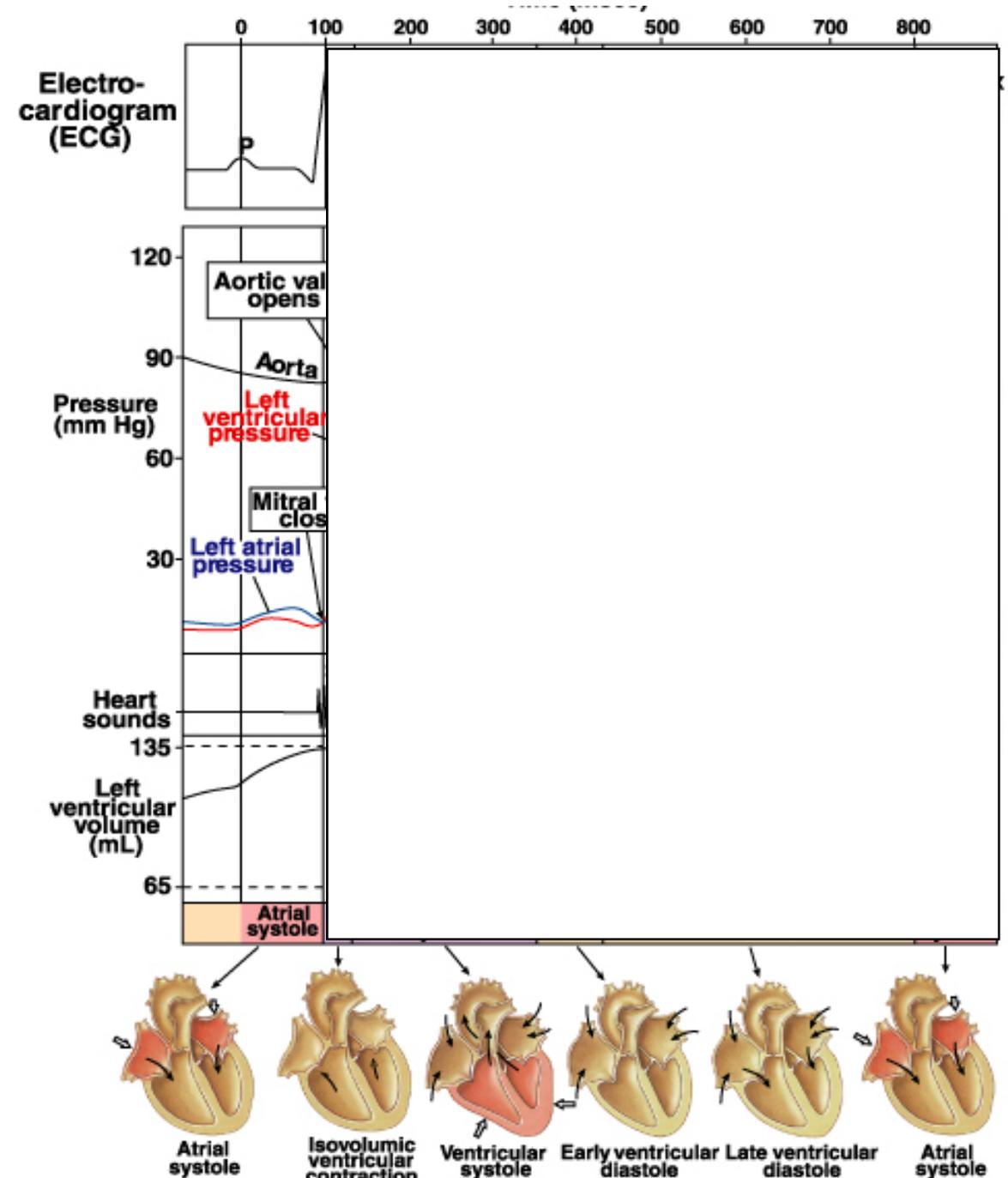
- The phases of cardiac cycle are:

- 1- Atrial systole.
- 2- Ventricular systole
- 3- protodiastolic phase.
- 4- ventricular diastole.



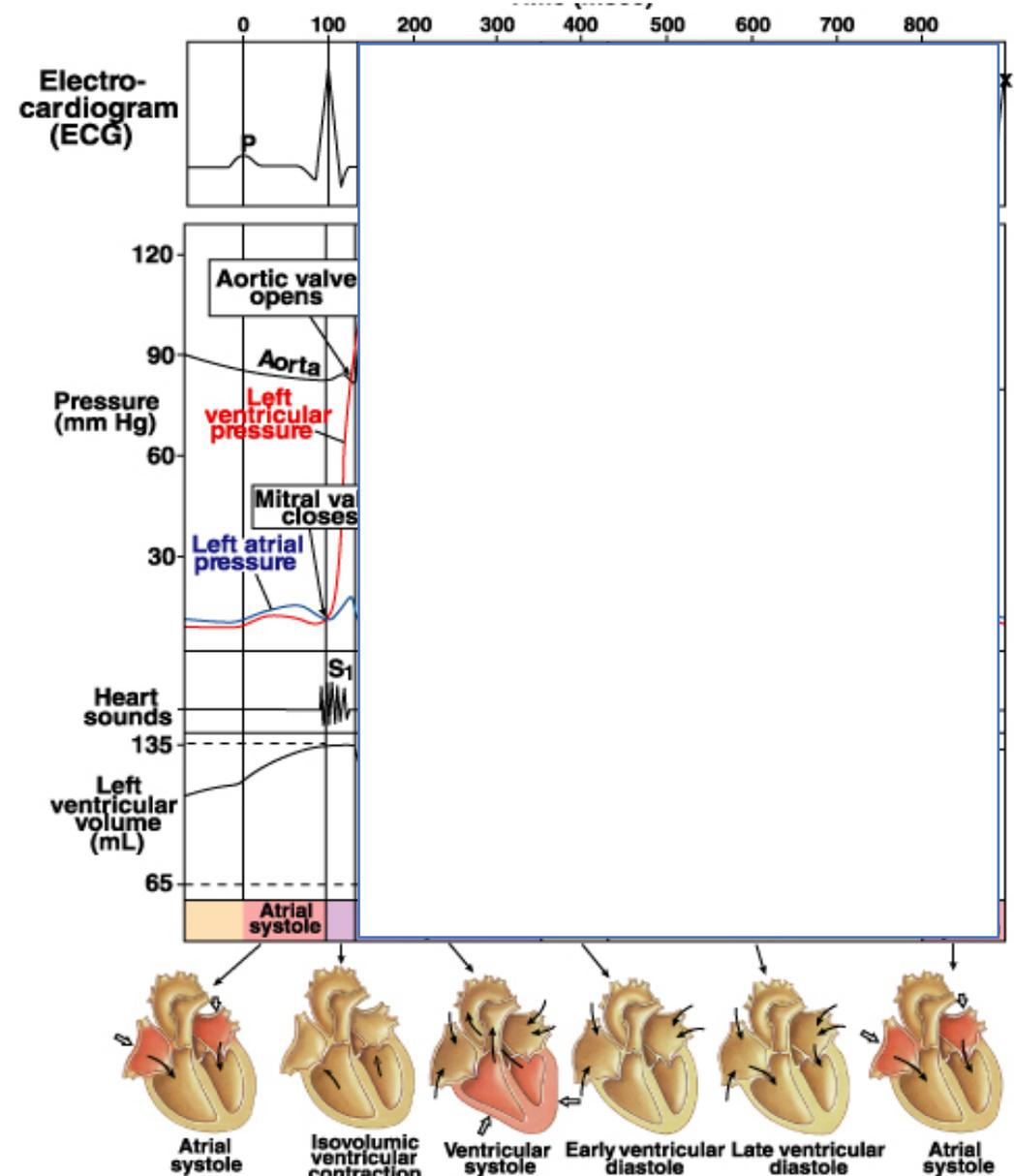
Atrial systole

1. Duration: 0.1 sec.
2. Atrial P: \uparrow from 0 to 2 mmHg then \downarrow again.
3. Ventricular pressure: \uparrow slightly due to rush of blood from atria, then \downarrow again as the ventricles are still relaxed.
4. Ventricular volume: \uparrow due to entry of blood from atrium to ventricle.
5. Aortic pressure: \downarrow gradually due to continuous flow of blood into peripheral circulation.
6. Valves: A-V valves opened, S.L. valves closed
7. Heart sounds: S4
8. ECG: P wave.



Isometric contraction phase

1. **Duration:** 0.05 sec.
2. **Atrial P:** ↑ slightly due sudden closure of A-V valves → ballooning of cusps of AVV toward the atrium.
3. **Ventricular pressure:** ↑ from 0 to 80 mmHg and the ventricle is a closed chamber.
4. **Aortic pressure:** ↓ to reaches its lowest value (diastolic bl.p.)= 80 mmHg due to continuous flow of blood into peripheral circulation.
5. **Ventricular volume:** kept constant.
6. **Valves:** A-V valves closed, S.L. valves closed
7. **Heart sounds:** early part of S1
8. **ECG:** QRS.



MCQ

What is the normal duration of ventricular systole?

- a) 0.1 second
- b) 0.2 second
- c) 0.3 second
- d) 0.4 second
- e) 0.5 second

Answer: c



Heart rate

Physiological Variations of Heart Rate

1- Age: New born infant: 120 b/m.

Adult: 70 b/m.

2- Gender: higher in females than males.

3- Physical training :

• In athletes : in resting conditions (50 – 60 b/m).

4- Sleep:

- quiet sleep → ↓ HR

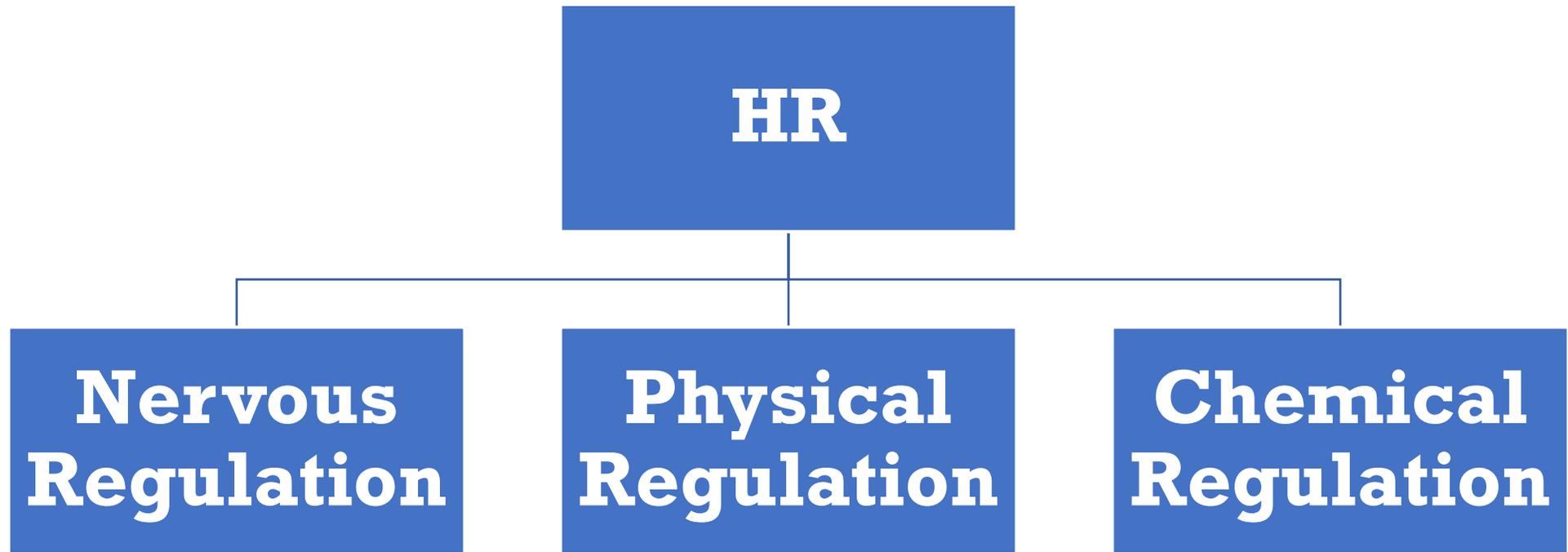
5- Emotions:

- usually ↑ HR above 100 b/m

6- Muscular exercise :

- usually ↑ HR above 120 b/m

Regulation of Heart Rate



Nervous Regulation of HR

**Nervous
regulation of HR**

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graph TD; A[Nervous regulation of HR] --> B[Impulses from higher centers in brain]; A --> C[Impulses from other parts of the body];
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**Impulses from
higher centers in
brain**

**Impulses from
other parts of the
body**

1. Impulses from CC

a- Conditioned reflex:

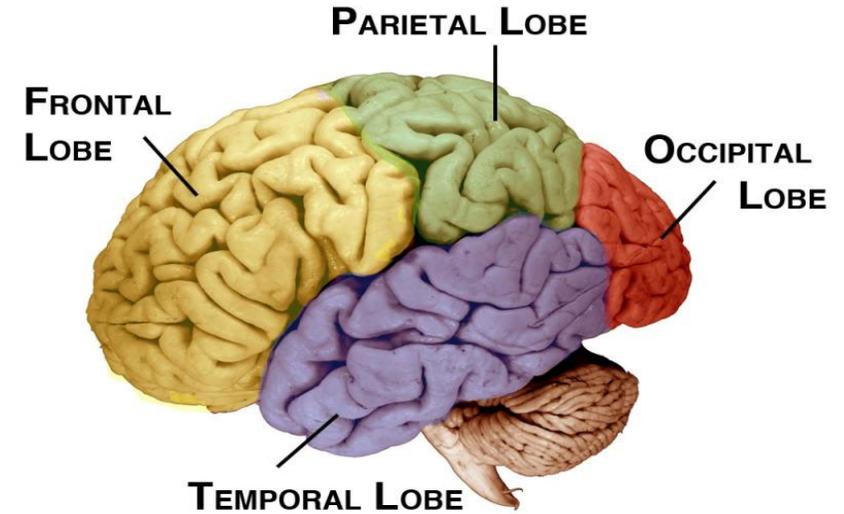
Visual, smell or auditory stimuli → stimulate certain areas in the **frontal lobe** of the cerebral cortex → **tachycardia or bradycardia.**

b- Voluntarily:

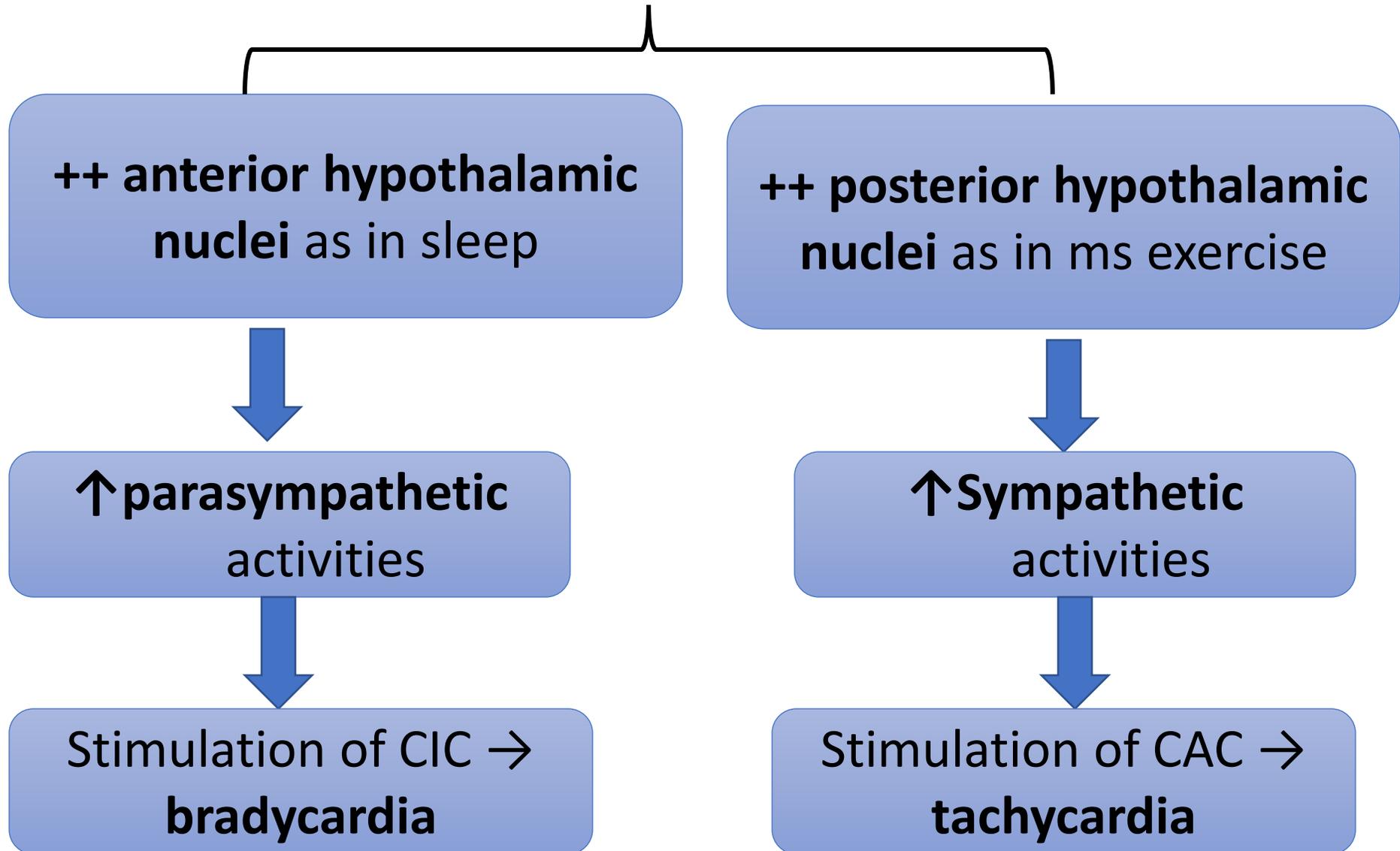
Some people can **increase or decrease** their heart rate voluntarily as in **practitioner of yoga.**

c) Emotions:

- Most emotions e.g. fear, anger → ↑ HR.
- Sudden shocking news → ↓ HR.



2. Impulses from Hypothalamus



Impulses from CVS

Bainbridge Reflex

*This reflex states that "increased cardiac filling i.e. right atrial pressure, leads to **reflex acceleration** of the heart.

* Mechanism:

- Stimulus: ↑ right atrial pressure.
- Receptors: Type A atrial baroreceptors
- Afferent: vagus nerve.
- Center: stimulation of CAC and inhibition of CIC.
- Efferent: sympathetic fibers.
- Effector organ: SAN.
- Effect: ↑ HR.

Marey's Law

*The heart rate is inversely proportional to the ABP provided that other factors that influence the HR remain constant.

*Mechanism:

- Stimulus: increase ABP.
- Receptors: arterial baroreceptors in the carotid sinus and aortic arch.
- Afferent: carotid sinus and aortic nerves.
- Center: inhibition of CAC and stimulation of CIC.
- Effect: ↓ HR.

MCQ

What is the normal range of heart rate at rest in adults?

- a) 40-60 beats/ minute
- b) 60-90 beats/ minute
- c) 90-100 beats/ minute
- d) 100-110 beats/ minute
- e) 110-130 beats/ minute

Answer: b



Cardiac output

Definitions



- **Cardiac output (COP):** It is the volume of blood pumped by each ventricle **per minute**.
- **Normally**, it is about **5 liters/minute** and is equal for both ventricles.
- **End diastolic volume (EDV):**
 - It is the volume of blood in the ventricles **at the end of diastole**.
 - It is about **110 – 130ml**.



- **End systolic volume (ESV):**

- It is the volume of blood in the ventricle **at the end of systole.**
- It is about **40-60 ml.**

- **Stroke volume (SV):**

- It is the volume of blood pumped by each ventricle **per beat.**
 - $SV = EDV - ESV = 130 - 60 = \underline{70ml}$
- **COP** = **SV x HR** = 70 x 70 = **4900** ml/min at rest.



- **Cardiac index:**

- It is the **volume of blood pumped by each ventricle / m² of body surface area / minute.**
- It is about **3.2 L/min/m².**
- It is used to **compare COP** between different individuals.

MCQ

What is the normal value of end systolic volume?

- a) 40-60 ml
- b) 20-40 ml
- c) 60-80 ml
- d) 80-100 ml
- e) 100-120 ml

Answer: a



Arterial blood pressure

Arterial blood pressure (ABP)



- **Def:** as the lateral force exerted by the moving column of blood on the lateral wall of arteries.

- **Types:**

1-Systolic blood pressure

- **Def:** This is the maximum pressure created inside the arteries during ventricular systole.

- **Value:** 90-140 mmHg

2-Diastolic blood pressure

- **Def:** This is the minimum pressure which remains inside the arteries at the end of ventricular diastole.

- **Value:** 60-90 mmHg

3-Pulse pressure: It is difference between systolic and diastolic blood pressures, which equals about 40 mmHg.



4-Mean systemic ABP:

- This is the average pressure in the systemic arteries throughout the cardiac cycle.
- As the systole is shorter than the diastole, the mean ABP is less than halfway between the systolic and diastolic pressures.
- Therefore, it is usually calculated as follows:

Mean ABP = diastolic pressure + 1/3 pulse pressure = 80 + 13 = 93 mmHg

MCQ

What is the normal value of pulse pressure?

- a) 60 mmHg
- b) 40 mmHg
- c) 20 mmHg
- d) 80 mmHg
- e) 100 mmHg

Answer: b



Physiological regulation of arteriolar diameter and tissue blood flow

(I) Local regulatory mechanisms (local tissue blood flow)



(1) Tissue metabolites:

- **↑ metabolism** in a tissue **→** **↑ formation of vasodilator substances** (as adenosine, CO_2 , lactic acid, K^+ , H^+ histamine) **→ VD**
→ **↑ tissue BF** **→** removal of metabolites.

(2) Oxygen supply to tissue:

- **↓ O_2 supply** to tissues (as in high altitude) **→** precapillary sphincters would open **→** **↑ tissue BF**.



(3) Autoregulation of blood flow:

- **Def:** Autoregulation is an **intrinsic mechanism** by which the **tissue** can **maintain its local BF** relatively constant in spite of moderate changes in **perfusion pressure**.
- **Site:** Renal, coronary, skeletal muscle and cerebral circulations.



• Mechanisms:

a) Metabolic theory:

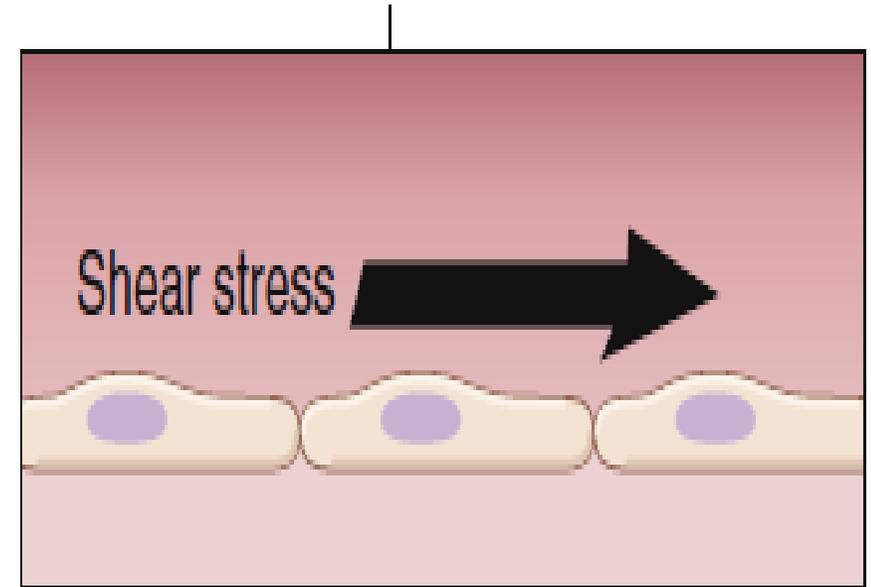
- \uparrow ABP \rightarrow \uparrow BF \rightarrow supply more O_2 and nutrients to tissues \rightarrow VC of blood vessels \rightarrow \downarrow BF back to normal.
- \downarrow ABP \rightarrow the reverse occurs.

b) myogenic theory:

- \uparrow ABP \rightarrow \uparrow BF \rightarrow sudden stretch of small vessels \rightarrow contraction of smooth muscles of vascular wall \rightarrow \downarrow BF back to normal.
- \downarrow ABP \rightarrow the reverse occurs.

(4) Endothelial – derived relaxing factor (nitric oxide) (NO)

- Rapid flow of blood through the arteries → **shear stress (friction force)** on **endothelial cells** → **↑ NO release** → relaxation and **VD of arteries**. Also, **NO** → **VD of large upstream arteries** → further **↑** of blood flow.



(II) Humoral (chemical) regulation of arteriolar diameter

(I) Vasoconstrictor agents:

1- Epinephrine and norepinephrine

- NE → powerful VC - Epinephrine → less VC

2- Angiotensin II

3- Antidiuretic hormone (ADH) (vasopressin).

4- Endothelin:

- Release from damaged endothelium of most blood vessels.

- Actions: VC to prevent excessive bleeding



(II) Vasodilator agents:

1- Bradykinin

- * VD
- * ↑ capillary permeability

2- Histamine:

- * VD
- * ↑ capillary permeability

3- Prostaglandins

4- Atrial natriuretic peptide (ANP)

MCQ

Sympathetic vasoconstrictor nerves primarily release which chemical transmitter?

- a) Acetylcholine
- b) Norepinephrine
- c) Dopamine
- d) Serotonin
- e) Histamine

Answer: b



Special circulation

Coronary circulation



- The coronary blood flow:

- During rest: It is about 250 ml/minute, (5% of COP).
- In severe exercise: The coronary blood flow ↑ to 3-4 folds.

Control of coronary blood flow



(I) Intrinsic mechanisms (Auto regulation):

- It is the main mechanism controlling CBF.
- O₂ demand and local metabolites are the **major regulators of CBF.**

- ↑ cardiac activity (e.g. during exercise) → ↓ O₂ → coronary V.D & ↑ CBF due to:



i- Direct relaxing effect of ↓ O₂ on smooth muscles of vessel wall.

ii- ↓ O₂ → anaerobic oxidation → accumulation of metabolites as CO₂, & bradykinin → V.D.

- ↓ cardiac activity → ↑ O₂ and ↓ metabolites → ↓ CBF.

(II) Extrinsic mechanisms:

1- Nervous factors:

	a) Sympathetic stimulation	b) Parasympathetic stimulation
• Direct effect:	<p><u>Direct vasoconstrictor effect due to:</u></p> <ul style="list-style-type: none"> -VC due to stimulation of α adrenergic receptors. -Mild VD due to stimulation of β_2 adrenergic receptors. 	<p><u>Direct vasodilator effect.</u></p>
• Indirect effect:	<p>Sympathetic stimulation $\rightarrow \uparrow$ metabolic activity of heart \rightarrow strong VD.</p>	<p>PS stimulation $\rightarrow \downarrow$ metabolic activity of heart \rightarrow strong VC</p>
• Net effect	<p>VD and \uparrow coronary BF</p>	<p>VC and \downarrow coronary BF</p>



Pulmonary circulation

- Functions of pulmonary circulation:

1. Transport of venous blood from right side of heart to left side.
2. Arterialization of venous blood during its passage through lungs (removal of CO_2 and receiving O_2).
3. Filtering action: pulmonary cap filters venous bl from any clots, or foreign particles → preventing them from entering arterial blood.

Regulation of pulmonary blood flow and pulmonary blood pressure



(I) Intrinsic mechanism:

(II) Extrinsic mechanism:

(II) Extrinsic mechanisms:

1- Nervous factors:

Vagal stimulation	Sympathetic stimulation
Produce <u>VD</u> of pulmonary blood vessels & ↓ pulmonary BP	Produce <u>VC</u> of pulmonary blood vessels & ↑ pulmonary BP

2- Chemical factors:



VD of pulmonary arteries

- Acetylcholine.
- Nitric oxide (NO)

VC of pulmonary arteries

- Catecholamines.
- Angiotensin II.
- Serotonin.



Cerebral circulation

- Normal value of cerebral BF:

- In adults → 750 ml/min → (brain weight = 1400gm).

- Factors regulating cerebral BF:

- (I) Intrinsic mechanism (Autoregulation):

- Means keeping the cerebral blood flow relatively **constant** with variation of ABP from **70 - 150 mm Hg**.

- Mechanisms:

1- Myogenic mechanism:

a) \uparrow ABP \rightarrow stretch of the vascular wall \rightarrow smooth muscle contraction \rightarrow V.C \rightarrow \downarrow CBF back to its normal level.

b) \downarrow ABP \rightarrow the opposite occurs.

2- Metabolic mechanism:

a) ↑ ABP → Local ↑ O₂ tension and ↓ CO₂ and H⁺
→ V.C of cerebral vessels → ↓ CBF back to its normal level.

b) ↓ ABP → Local ↓ O₂ tension and ↑ CO₂ and H⁺
→ V.D of cerebral vessels → ↑ CBF back to its normal level

MCQ

What is the normal coronary blood flow at rest?

- a) 100 ml/min
- b) 250 ml/min
- c) 500 ml/min
- d) 1 liter/min
- e) 750 ml/min

Answer: b



Capillary circulation

Capillary blood pressure

- Value:

- At arterial end → 30-35 mm Hg.

- At venous end → 10-15 mmHg.

- Mean cap BP (pressure at the middle of cap) → 25 mmHg.

- Factors affecting cap BP and cap BF:

- (I) Extra capillary (passive factors):

- a) Diameter of arterioles:

- **VD** of arterioles → ↑ cap BF & cap BP.

- **VC** of arterioles → reverse effect.

- b) venous pressure

- ↑ [as in **heart failure** (generalized) or local obstruction of vein by **thrombosis**] → ↑ cap BP & ↓ cap BF.

(II) Active contraction of capillaries:

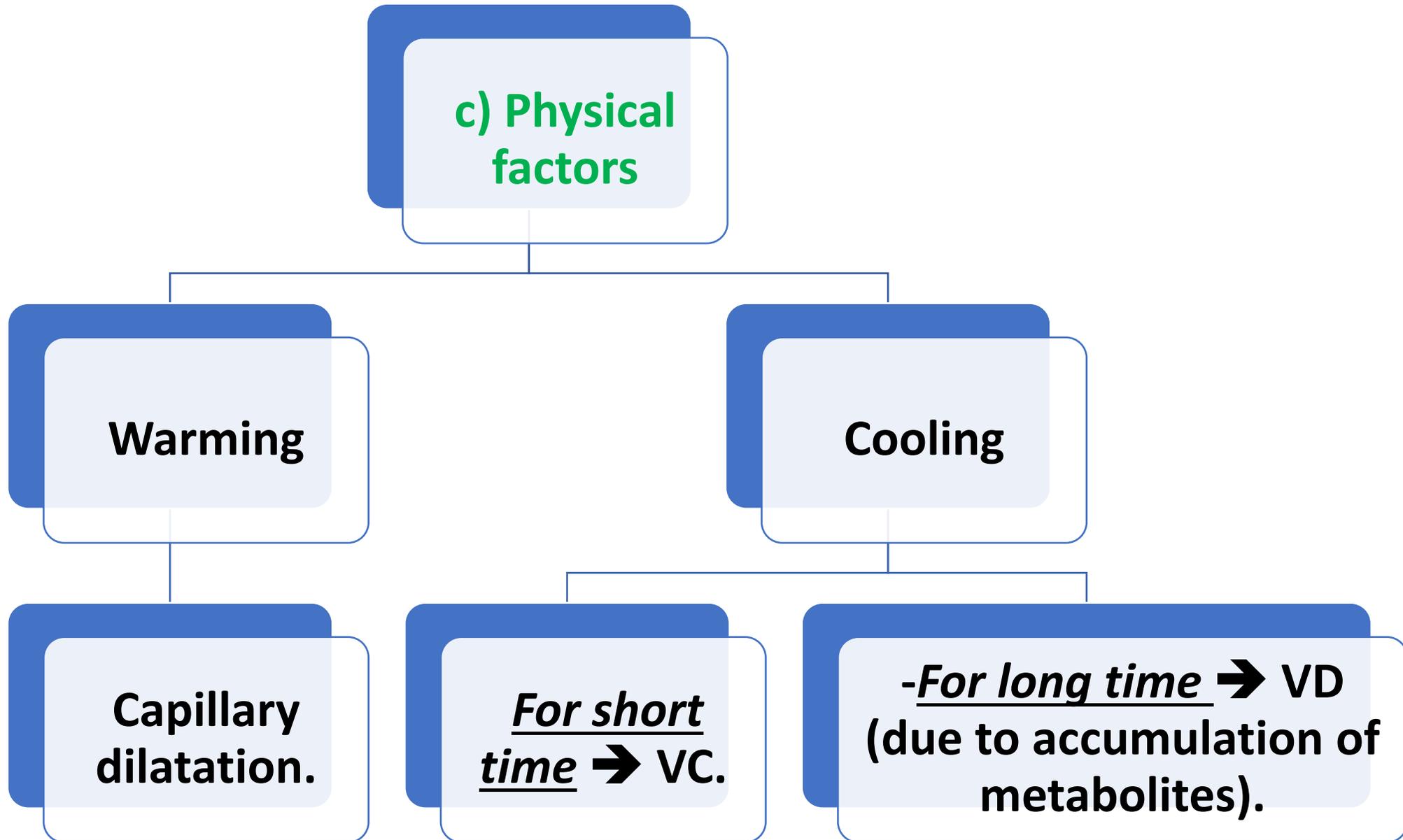
• Factors affecting cont. of capillaries

a) Chemical factors:

VC of capillaries	VD of capillaries
<ul style="list-style-type: none">-Adrenaline.-Noradrenaline.-Angiotensin II.-Vasopressin.	<ul style="list-style-type: none">-Metabolites: \uparrow CO₂, \uparrow H⁺, \downarrow O₂.-Acetylcholine.-Histamine.

b) Nervous factors: No nerve supply to true capillaries

c) Physical factors:



Mechanisms of trans capillary exchange of fluids



(I) Diffusion:

- **Def:** It is the means by which water and dissolved substances are transferred between plasma and interstitial fluid.
- **Passive process.**



- Factors affecting diffusion:

1. Concentration gradient: Diffusion of a substance occurs from **higher** to **lower** concentration.
2. Surface area: The greater the surface area available for diffusion, the **more** will be the rate of diffusion of a substance.
3. Capillary permeability: The cap wall behaves as a **semi permeable membrane** through which diffusion of different substances occurs.

MCQ

What is the total surface area of all the capillaries in the human body?

- a) 100-200 m²
- b) 300-400 m²
- c) 500-700 m²
- d) 800-900 m²
- e) 900-1000 m²

Answer: c



Lymphatic and venous circulations

Lymphatic circulation

➤ Function of lymphatic system:

1) Drainage of excess interstitial fluid filtered from capillaries to blood.

2) Drainage of filtered proteins (can not be reabsorbed by capillaries).



3) Absorption of fat from intestine.

4) Functions of lymph nodes:

- a. Filtration of lymph.
- b. Formation of lymphocytes.
- c. Formation of immune bodies.

➤ Factors that maintain lymph flow:

1. Rhythmic contraction of smooth muscles in the wall of lymphatic vessels.
2. Skeletal muscle contraction compresses the lymph vessels → ↑ lymph flow.
3. Arterial pulsations are mechanically conducted to lymph vessels, which may help lymph flow.



4. **Gravity helps** the lymph flow from parts above the level of the heart, but **antagonizes** it from parts below the level of the heart.

5. **Hydrostatic pressure of the interstitial fluid** is normally negative (-3 mmHg), this helps the lymph flow.

Venous circulation

➤ Functions of veins:

1. Drainage of blood from all parts of the body to the heart.
Also the **lymph drainage** opens into the venous system.
2. Blood reservoirs, they contain about **3 liters** of blood.
3. Venous pump, it helps in **propelling the blood** towards the heart and helps to **regulate the cardiac output**.

Central venous pressure (CVP):

• **Def:** It is the venous pressure in big veins at their entrance with the right atrium, or the intrathoracic portions of vena cavae.

• **Values:**

❑ 4.6 mmHg in recumbency and 2 mmHg on standing.

❑ 2 mmHg during inspiration and 6 mmHg during expiration.

• Factors affecting CVP:

CVP is increased in:

1. +ve intrathoracic pressure e.g. straining.
2. Hypervolemia (blood transfusion).
3. Sympathomimetics due to venoconstriction & ↑ venous return
4. Recumbency (CVP ↑ to 4.6 mmHg)
5. Congestive heart failure (CHF).

CVP is decreased in:

1. -ve intrathoracic pressure during breathing.
2. Hypovolemia (hemorrhage).
3. Sympatholytics due to venodilatation & ↓ venous return.
4. Standing (CVP ↓ to 2 mmHg).

MCQ

Where do the thoracic and right lymphatic ducts empty lymph?

- a) Inferior vena cava
- b) Jugular vein
- c) Subclavian veins
- d) Superior vena cava
- e) Brachial artery

Answer: c



Physiological response of CVS to haemorrhage and shock

Haemorrhage

• Manifestations

1- ↓ ABP.

2- Rapid, weak, feeble pulse.

3- Respiration:

▪ Rate: rapid.

▪ Depth at 1st deep then shallow.

4- Skin: pale, cold, moist, and slightly cyanotic.

5- Oliguria.

6- Fainting.



Effects of haemorrhage

(I) Immediate compensatory effects:

1- Cardio vascular system:

a) Cardiac acceleration (Increase HR):

* Importance of ↑ HR:

↑ DBP → ↑ mean systemic ABP which determine BF through cerebral and coronary blood vessels.

* Causes of \uparrow HR :

1. \downarrow ABP \rightarrow \uparrow HR (Marey's Law).
2. \uparrow **adrenaline** secretion \rightarrow stimulation of SAN directly.
3. Haemorrhage \rightarrow **hypoxia** \rightarrow stimulation of **CAC** directly.

b) Vasoconstriction:

*** Importance of VC:**

- **It causes generalized VC** except in the cerebral and coronary vessels → helps VR → maintain cardiac filling, COP, and ABP.

* Causes of VC:

- 1- ↓ depressor impulses from arterial baroreceptors.
- 2- ↑ secretion of epinephrine and norepinephrine.
- 3- ↑ secretion of vasopressin.
- 4- ↑ Release of serotonin from disintegrated platelets.
- 5- Renal ischemia → VC.





2- Contraction of blood reservoir:

*** Importance:** Contraction of blood reservoirs as spleen

→ add its blood content into the general circulation.

• **Causes:**

- ↑ sympathetic activity.
- ↑ adrenaline secretion.



3- Respiratory changes:

* Importance:

- VC of pulmonary blood vessels.
- Acceleration of respiration



* Causes of ↑ respiration rate:

1- ↓ BF through **central chemoreceptors & respiratory center neurons** → Local accumulation of metabolites.

2- ↓ inhibitory impulses from arterial baroreceptors as a result of hypotension.

4- Blood changes:

a) Coagulation of blood.

b) Serotonin release from disintegrated platelets → VC of injured blood vessels.

c) Adrenaline release → help formation of fibrinogen, prothrombin and factor V in the liver → blood coagulation.

d) Erythropoietin release → stimulates RBCs production by bone marrow.

Circulatory shock



- **Def:** Inadequate tissue perfusion or insufficient BF to supply tissue requirement and remove waste products.

- **Types:**

(I) Hypovolemic shock

(II) Low resistance shock

(III) Cardiogenic shock



Hypovolemic shock

- Means: ↓ blood volume. (haemorrhage is the most common cause).
- Characterized by:
 - 1- Hypotension.
 - 2- Rapid weak pulse.
 - 3- Rapid respiration.
 - 4- Pale cold sweaty skin.
 - 5- Thirst.

Low resistance shock



- **Cause:** widespread VD \rightarrow marked \uparrow in capacity of vascular system (with normal blood volume) \rightarrow \downarrow mean circulating pressure (MCP) \rightarrow \downarrow VR, COP, ABP.



Cardiogenic shock

- Cause: sever ↓ in pumping action of heart e.g.
myocardial infarction → ↓ COP and ABP.
- Manifestations:
 1. As those of **hypovolemic shock**.
 2. Manifestations of **heart failure** and **lung congestion**.

MCQ

What is the cause of hypovolemic shock?

- a) Widespread vasodilatation
- b) Decreased blood volume
- c) Decreased pumping action of the heart
- d) Severe vasoconstriction
- e) Myocardial infarction

Answer: b



Physiological response of CVS to exercise

Effect of exercise on circulation



I. General effects:

1- ↑ heart rate (HR) (up to 200/min) due to:

a) Emotional stimuli from cerebral cortex and hypothalamus → inhibit CIC and stimulate CAC → ↑ HR.

b) Stimulation of respiratory center by excess CO_2 → irradiates to stimulate CAC and inhibit CIC → ↑ HR.

c) Stimulation of chemoreceptors by \uparrow CO₂ & H⁺ & \downarrow O₂ tension \rightarrow stimulates CAC \rightarrow \uparrow HR.



d) Bainbridge reflex \uparrow HR (see before).

e) Alam-Smirk reflex from the active muscles \rightarrow \uparrow HR.

f) \uparrow body temperature, stimulates the hypothalamic RC, CAC and SAN \rightarrow \uparrow HR.

g) \uparrow adrenaline by suprarenal medulla produces direct stimulation of the SAN, \rightarrow \uparrow HR.

2-↑ VR due to:

a) Contraction of active muscles.

b) Respiratory pump: ↑ the -ve intrapleural pressure

→ suction of more blood towards the heart.

c) ↑ blood volume by contraction of **spleen**

d) Venoconstriction.

3- ↑ coronary blood flow:

a) Anrep's reflex.

b) Local vasodilatation by accumulated metabolites.

c) ↑ sympathetic stimulation.

d) ↑ catecholamines secretion.

4- ↑ stroke volume (up to 200 ml/beat) due to:

a) ↑ coronary BF.

b) ↑ sympathetic stimulation.

c) Direct action of adrenaline on myocardium.

d) Starling's law ($\uparrow VR \rightarrow \uparrow EDV \rightarrow \uparrow$ contraction).



MCQ

What is the effect of exercise on circulation?

- a) Decreased stroke volume
- b) Decreased heart rate
- c) Decreased cardiac output
- d) Increased venous return
- e) Decreased coronary blood flow

Answer: d