

2nd Lecture

Cardiac electrical activity

Physiology Team - 430

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Heart's ability to beat is **intrinsic** : without nerve impulses

The function of the nerve is only regulate impulse not produce impulse in heart

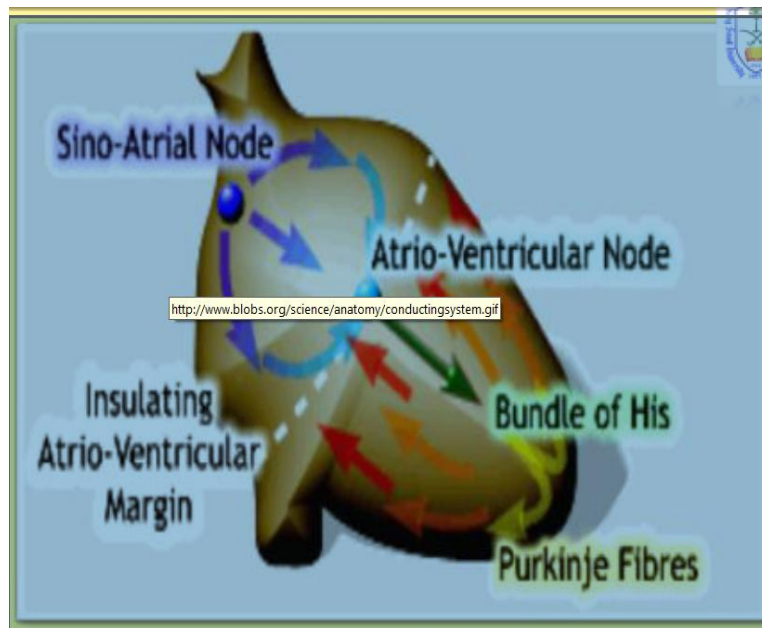
- if you cut nerve that supply heart .the will continue to beat and this **called Rhythmicity**
- **Syncytium** : is stimulation of one myocardial cell lead to stimulation of all myocardial cell because presence of gap junction .
- **Gap junction** is connection between 2 adjacent myocardial cell which allow to transmit impulse between cell

Intrinsic conducting system (Nodal System) of the heart:

network of specialized non-contractile myocardial tissue(called conducting tissue)

Cardiac Conduction System:

- Generates & conducts impulses throughout the heart
- Flow of electrical current stimulates myocardial contractions, producing effective pumping of blood & optimize CO (**cardiac outcome**)
- Ensures the heart beats as a coordinated unit **HOW** (two atrium contract together then relaxation of atrium and at same time the two ventricles contract together)



To explain :

The SA (sino-atrial) node is **the cardiac pacemaker = that generate impulse =80 beat .**

The impulse then **go to the two atria** (include bachmanns bundle which in the left atrium) then they contract but the impulse cannot directly go to the two ventricles **cause there a fibrous ring** or band which **isolated** (cannot make the impulse pass throw it)

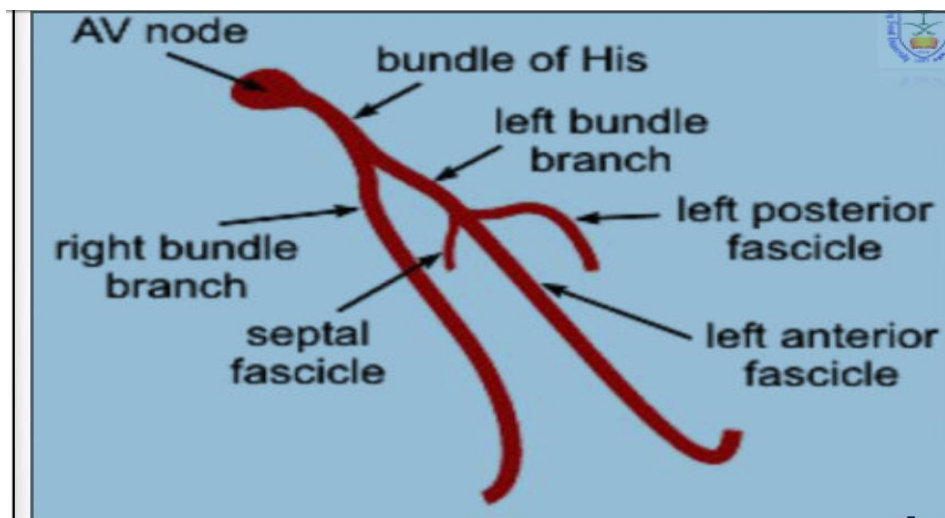
HOW CAN THE IMPULS PASS TO THE TWO VENTRECALS?

By the bundle of his (the link between the atrium and ventricles).(AV node slower the impulse to give time to atrium to complete contraction to filling ventricle before contraction)

The impulse passes from the **bundle of his** to the **right bundle** branch and **left bundle** branch then it reaches **the purkinje fibers** (**thinnest** branches in the conducting tissue)

The SA and AV node is slow (action potential an velocity) but than purkinje fibers which is **fastest** fibers. SA or AV conducting velocity = .05m/s but purkinje=4m/s

Note that they are **not nerve** they are specialized **non-contractile . myocardial tissue.**



bundle of his divide to **two** branches :

right bundle branch and **left** bundle branch

The left bundle branch have three branch (left posterior fascicle , left anterior fascicle and septal fascicle)

WHY THE LEFT SIDE IS MORE BRANCH THAN THE RIGHT ?

Cause the left side is **more thick**, pump the blood to all body and to make the two ventricles pump together).

Intrinsic Firing Rates:

3 potential areas capable of beginning cardiac conduction:

1) SA node(pacemaker)

2) AV node

3) Purkinje

SA node	AV node	purkinje
الملك	ولي العهد	نائب ولي العهد
<u>Cardiac pacemaker:</u> Generate the impulse	في حالة إصابة SA node تقوم ب generate impulse	في حالة إصابة AV node تقوم ب generate impulse
Cause it have the highest firing rate which is 80-70 bpm	Cause the firing rate is higher than the purkinje which is 45-60 bpm	Cause the firing rate is the lowest which is 15-45 bpm

The direction of the impulse:

1st Atrial spread

■ from SA-node to:

- 1- Three inter nodal connection to A-V node
- 2- **Circus stimuli**: bachmanns bundle pathways to atria (right and left)

2nd Ventricular spread

From AV then to the rest to conducting system to ventricle

■from apex of the heart TO base, via Purkinje fibers
endocardium

Note :

لا يمكن أن ينقبض الأذنين مع البطينين في نفس الوقت.

(when the atria contract the ventricles relax and when the ventricles contract the atria relax).

- **The inotropic** is the force of contraction , **but**
- **The chronotropic** is the heart rate(HR) or the rhythm

Characteristics of Cardiac Conduction Cell:

- 1) Automaticity
- 2) Excitability
- 3) Conductivity

I : Automaticity (Rhythmicity) Initiates Action Potentials:

Ability to initiate an electrical impulse and Ability of cardiac ms to contract in a regular **constant manner**.

- without nerve supply (not neurogenic)
- The Origin: is the SA node.

The pacemaker of the heart is the SA- node:

- 1) Contains P - cells
- 2) Has **slowest** conduction velocity.
- 3) Its fibers have an unstable RMP (**prepotential**) .

(وهذا يؤدي لانتاج ال AP)

Factors Affecting Myocardial Rhythmicity: (Chronotropic Effectors) :

1. Cardiac innervation: (ANS)

Sympathetic is increase HR

Parasympathetic is decrease HR.

2. Effect of ions concentration in ECF

↑ Ca is increase HR but ↑ K is decrease HR.

3. Physical factors:

(e.g. warming and exercise increase HR; cooling; decrease HR)

4. Chemical factors: (drugs)

.....

II: Excitability (Irritability) :

Ability to respond to electrical impulse by generating an action potential followed by a mechanical contraction

Relation between action potential & mechanical response :

Cardiac ms begins to contract few m sec after AP begins (Electrical impulse before the mechanical work)

Mechanical response consists of contraction (**systole**) & relaxation (**diastole**).

Diastole begins at the end of the plateau

.

RMP(resting membrane potential) of ventricular ms ≈ -90 mV

Threshold = -40 mV

Trans-membranous AP overshoots to $\approx +20$ mV

Action potential of heart muscle is biphasic action potential

Resting membrane potential (RMP): outside +ve , inside -ve

Heart action potential :

1- fast AP: For

a)atria

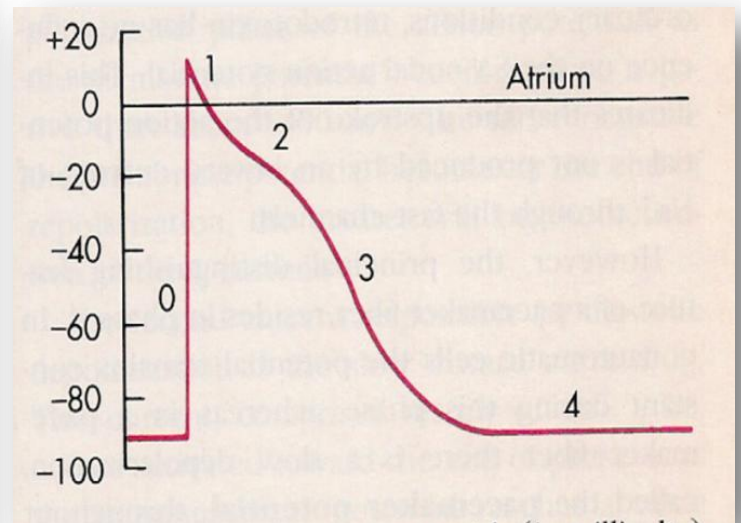
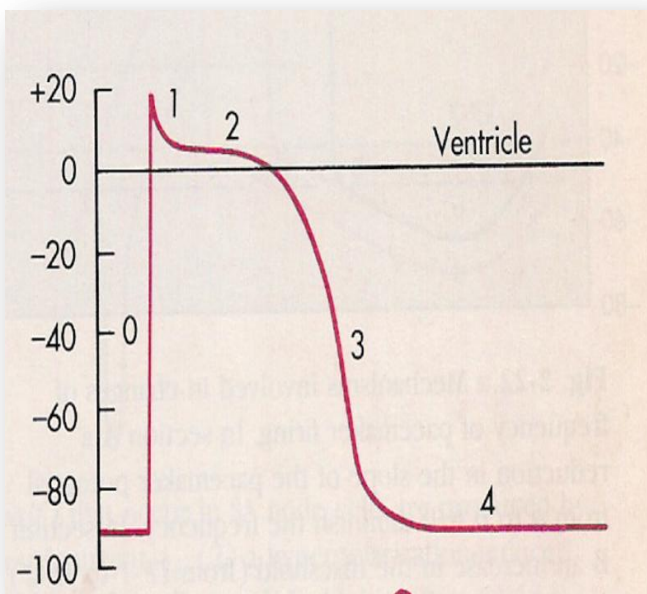
b)Ventricle

c) Purkinje fiber : (it make action potential but the diagram is like SA and AV node)

ventricle and **atrium** have the **same diagram** but only difference is in **duration**

Ventricle AP duration is =350 ms

Atrium AP duration =120 ms



Action Potential of Ventricular Muscle Characterized by presence of 5 phases :

Phase 0 : rapid depolarization (+ve inside -ve outside (stimulation))

Na channels open (Na influx)

From phase 1 to phase 4 they are repolarization :

Phase 1 early repolarization: Na channel close, fast K open (efflux)

Phase 2 (plateau) :

Ca⁺² channel open Ca⁺² influx(this main reason to casue plateau phase , fast K channel close ,)

Phase 3 delay repolarization : Ca^{+2} channel close,

- 1) Slow K channel open (efflux)
- 2) Fast K channel reopen (efflux)

Phase 4 : complete repolarization (resting potential) :

is due to :

- 1) **increase K-permeability**
- 2) protein inside cell (protein is -ve charge) .
- 3) **Na-K ATPase pump** .(that make 3Na out and 2K in)

All phases in atrium and ventricular AP are stimuli except duration (duration of ventricle =350 ms and atrium =120)

Purkinje fiber :

RMP=-70 mv

Duration of AP=400 ms

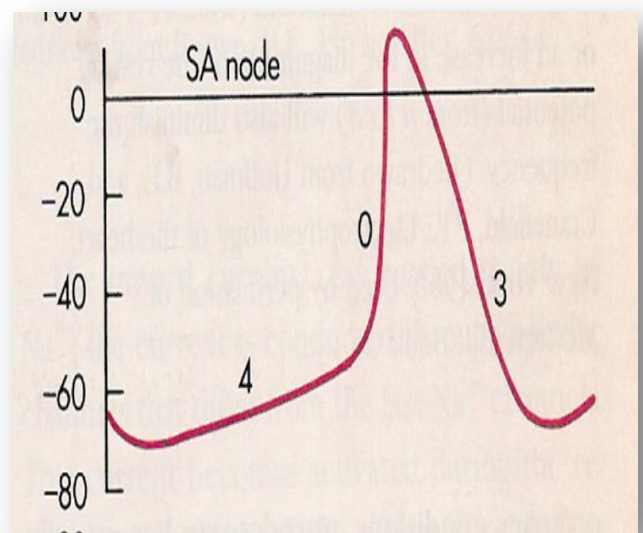
Conduction velocity =4m/s

Purkinje fiber has prepotential

Slow AP: SA node AV node:

0 = zero phase of SA or AV caused by entry of Ca^{+2} (instead of Na).

3 = Third phase or repolarizing phase of SA or AV : due to exit of K



4= prepotential or pacemaker AP or slow depolarization Potential
:due to :

1) close of K channel

2) entry of Na from outside to inside through **funny channel**.

3) entry of Ca^{+2} from out to in **through T-Ca channel**

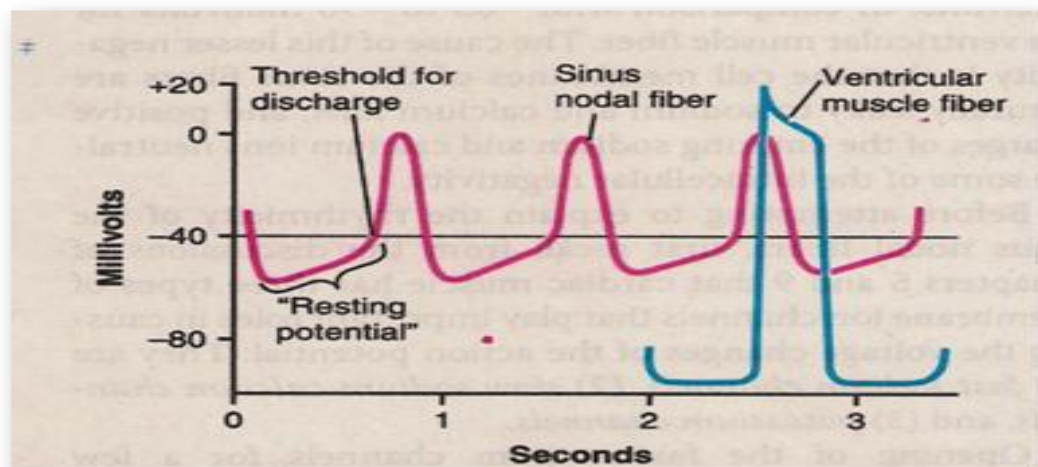
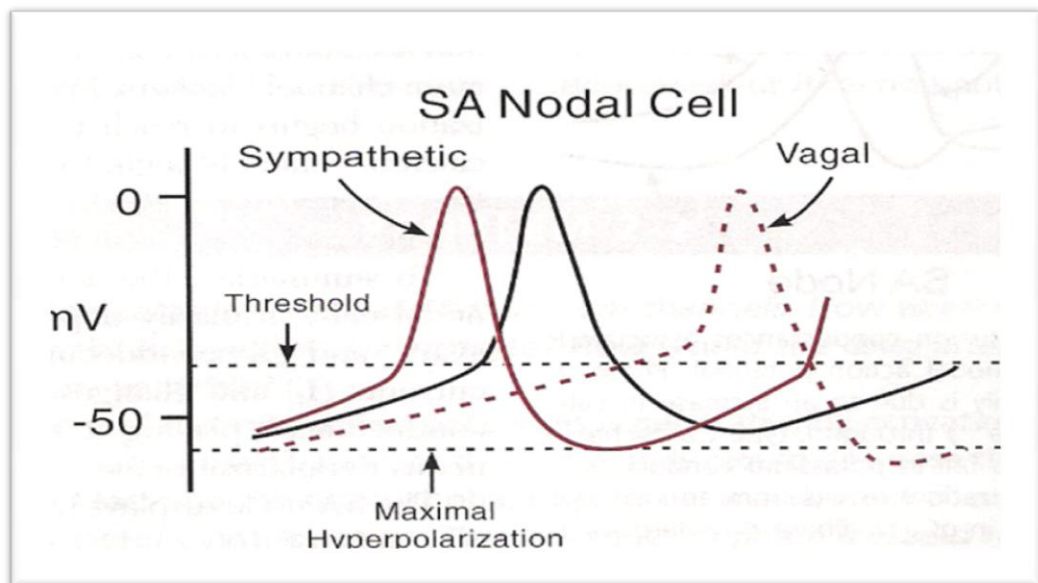
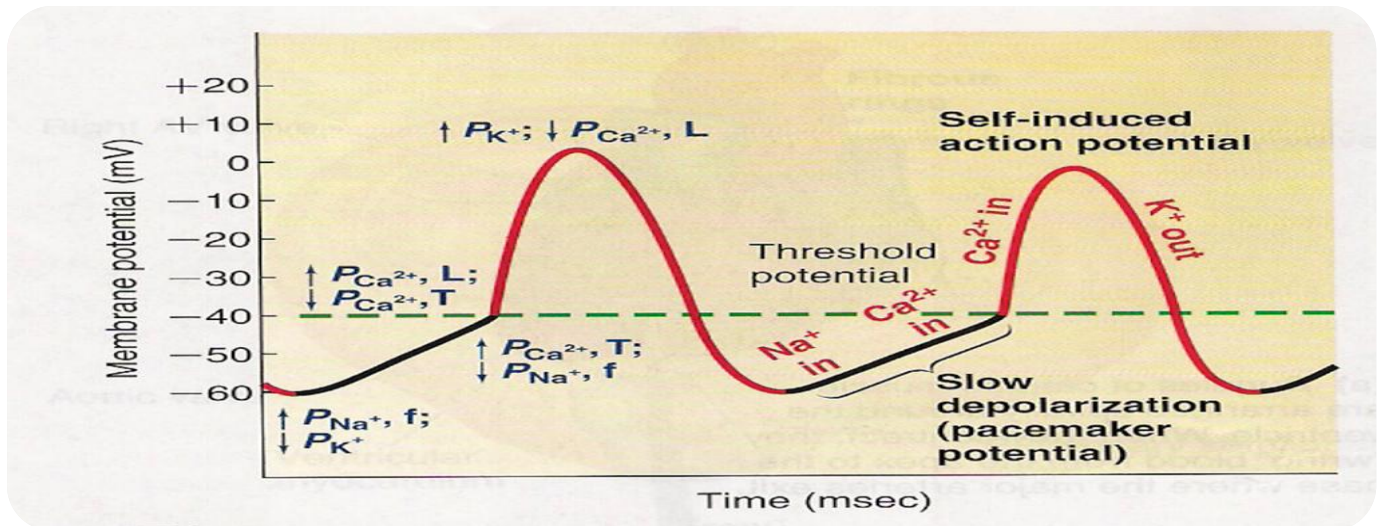
Note :the phase 1 and 2 are missing.

The prepotential start from hyperpolarization.

Funny channel : is channel that allow to enter of Na only during hyperpolarization.

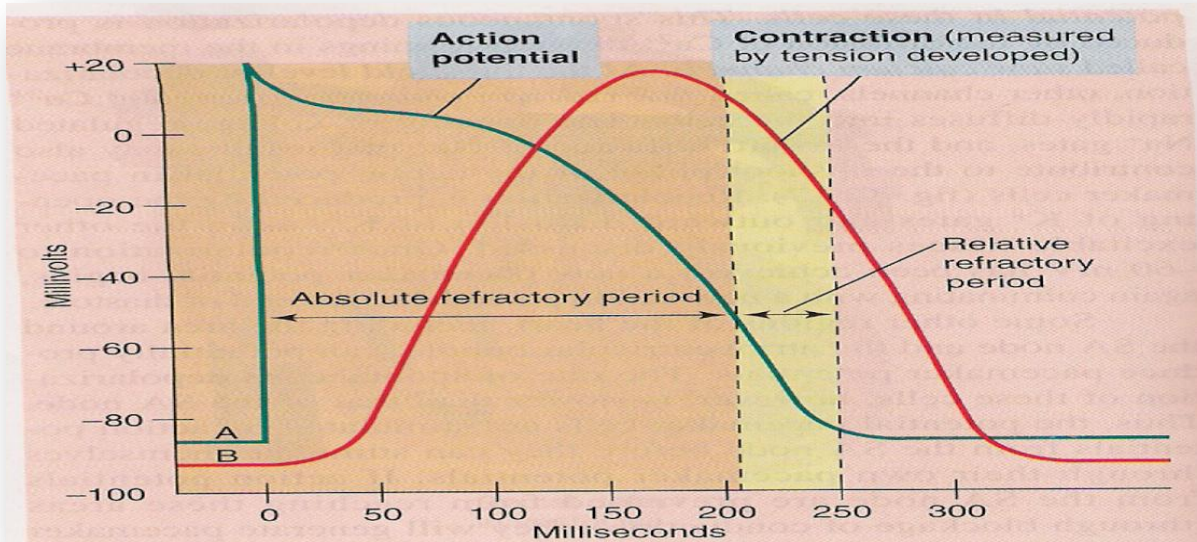
Parasympathetic (vagus nerve): supply SA(by right vagus) and AV (by left vagus) node only and make slope (**prepotential**) horizontal so **decrease** heart rate .

Sympathetic : supply all muscle of heart and make slope(**prepotential**) more vertical so **increase** heart rate .



Note : AP of ventricle occur faster than AP of SA or AV

Because ventricle AP because fast Na^+ entry but in SA or AV because slow Ca^{+2} entry.



1) absolute refractory period (ARP) : the second stimuli is unaffected whatever strong is .(250 ms)

2) relative refractory period (RRP) : the second stimuli can be affect if it stronger than threshold. Is due to K outflow from K channel .

3) Dangerous period (supranormal period):

Weaker stimuli < normal can excite the ms.

معناها ان فيه فترة تستجيب لـstimulus
اذا كان ضعيف جدا ولذلك سموها بالفترة الخطرة
وتسبب ventricular fibrillation

III: Conductivity:

Ability to transmit an electrical impulse.

Conduction Velocities of the Impulse :

- Allowing the atria time to contract
- Allow complete ventricular filling

(0.03 –0.05 m/sec) **(slowest in AV-node)**

- Allowing the 2 ventricles to contract at the same time simultaneously

(4.0 –5.0 m/sec). **(fastest in purkinje) .**

Delayed AV node:

Slight impulse delay 0.1 sec

AV-node has few number of intercalated discs & gap junctions

Functionally, AV node is made up of 3 zones:

1-Atrionodal(AN)

2-Nodal (N)

3-Nodal His (NH)

Good Luck