Membrane potential of cardiac muscles

In last lecture; murmurs is a sound that is caused by a turbulent blood flow.

**Normal moving (laminar flow),Features; 1-the blood is smoothly moving and the sound just comes from friction of blood flow movements with wall of blood vessels.
2-paraller layers.

**Abnormal flow (turbulent flow); 1-not smoothly sound 2-overlaping layers
3-the sound comes from; friction, overlapping with blood vessels.

**To distinguish between systole sound from diastole sound, you can use (sphygmomanometer).

**We have two types of cardiac action potential;

1-cardiac pacemaker (rhythm) regulation; it isn't responsible for generation of action potential, (Not true A.P)

**These are normally found in the sinoatrial and atrioventricular nodes of the heart.

2-myocardiac muscle ; atrium &ventricular contraction.(true A.P)(non-pacemaker cells)

****The** heart cells differ from other cells because they make regulation of A.P

****The regulator** of skeletal muscle movement is motor neuron and the motor neurons help primary to make A.P

****The typical** nerve cells must have true A.P to regulate A.P along the nerve.

Cardiac cells have special feature (its autorhythmic cells**), that mean; it doesn't need a neuron to make pumping & contraction. You can see this feature during transplantation of heart, (**in vitro)** you can hearing the blood pumping & cardiac contraction.

****The most challenge** of transplantation is to find a machine that can save a heart for long time.

**why was it a big challenge ?
cuz the thorax contains big blood vessels and bones so when making surgery u have to be careful not to affect the pressure of blood and this needs long time and the heart dies before we we transplant it ,but now we have a fast machine that solved this problem!!

****Autorhythmic happen due to pacemakers.**

**** pacemakers has an A.P, but we consider it not true A.P & not true resting potential .**

****Pacemaker cells = slow response & depolarization & A.P**

****The A.P for non pacemaker cells like a skeletal and nerve A.P, but with difference……**

(NON PACEMAKER A.P = FAST response & TRUE A.P)
******Why is AP slower in cardiac cells? cuz we need enough time foersystolic and diastolic filling

Compression	Skeletal muscle	Nerve muscle	Cardiac muscle
Duration of A.P	$(2\text{-}5)\times10^{-3}$ S (2-5) ms	1 ms (1×10^{-3})S	(200-400) ms $(200\text{-}400)\times10^{-3}$ s
Role of Ca+2 & Na+ channels	the depolarization phase caused by opening of Na+ channels	The depolarization phase caused by opening Na+ channels	**Non pacemaker** also like skeletal &nerve muscle & Ca+2 inflow prolong duration of A.P & platuea phase) **Pacemaker:** Ca+2 Involved in the initial depolarization phase of A.P

Important question

What is very important in the first events of true A.P??
-Inflow Na+ to change the charge (dramatically), that increase the positivity On *cell membrane.* (normally; positive outside the cell membrane, but in A.P; positive inside the cell. (This also occurs in non-pacemaker cardiac cells)

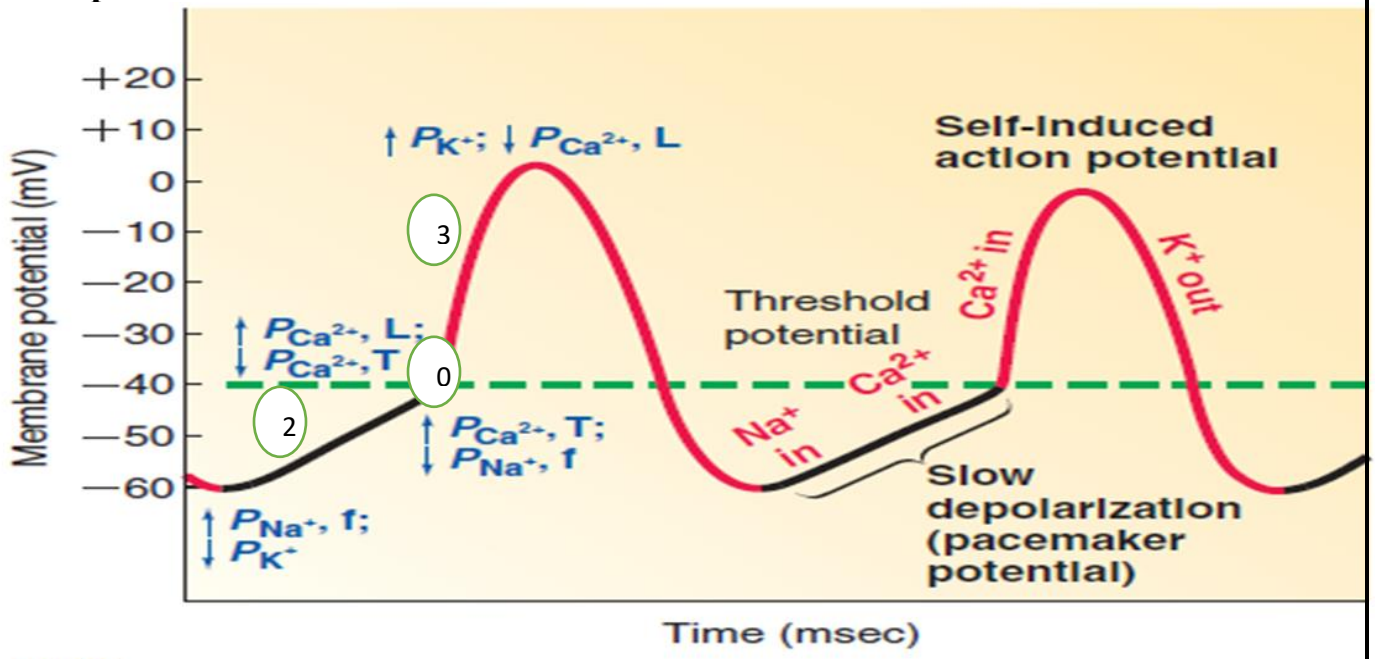
But A.P on the cardiac (pacemaker) cells doesn't happen like this…

NOTE;

The charge is changed due to inflow(influx) of Ca+2 ions **INSTEAD** of Na+ ions.

So:
**Cells within the sinoatrial (SA) node are the primary pacemaker site within the heart. These cells are characterized as having no true resting potential, but instead generate regular, spontaneous action potentials.
** Unlike non-pacemaker action potentials in the heart, and most other cells that elicit action potentials (e.g., nerve cells, muscle cells), the depolarizing current is carried into the cell primarily by relatively slow Ca++ currents instead of by fast Na+ currents.
**There are, in fact, no fast Na+ channels and currents operating in SA nodal cells. This results in slower action potentials in terms of how rapidly they depolarize. Therefore, these pacemaker action potentials are sometimes referred to as "slow response" action potentials

AP in pacemaker cells:



KEY

f = Funny channels
T = Transient-type channels
L = Long-lasting channels

Phase 1: Pacemaker Potential:

- Opening of voltage-gated Sodium channels called Funny channels (I_f or f channels).
- Closure of voltage-gated Potassium channels.
- Opening of Voltage-gated Transient-type Calcium (T-type Ca^{2+} channels) channels .

NOTE;

The step of of A.P is discussed by voltage-gated channels. (it doesn't affect when membrane is resting but we discuss it when we talk about REPOLARAZATION & DEPOLARAZATION)

**Another kind of channels to inflow of ions is K+.
what kind of channel that is always **opening?
It's a K+ leak channel, it's a passive channel(its not a relation with a polarization & depolarization).

The K+ ion always goes inside the cell,it is responsible to make a negativity intracellular than extracellular **.K+ doesn't make dramatically change like Na+. (RP)
THE cardiac cells have **a lot of channels** like(K+,Na+,Cl-)

Phase 2: The Rising Phase or Depolarization

- Opening of Long-lasting voltage-gated Calcium channels (L-type Ca^{2+} channels).

Large influx of Calcium.

A rising phase or a depolarization : it's a kind of a depolarization even if no true depolarization.

Ca+2 inflow inside cell through long-lasting voltage calcium channels.
***From the picture (Mv) will change from -60 to -40

The Ca+2 channels will work **before phase 2.**But it doesn't have a huge effect because it doesn't make a huge positivity and doesn't make a kind of depolarization.

Phase 0 (threshold) : (depolarization phase) rise the positivity inside the cell due to open a long-channel of Ca+2.

Phase 0 in S.M special because its only phase that the ion basis is K+, but in atrium and ventricular the ion basis is Na+.

Phase 3: The Falling Phase or Repolarization:

- Opening of voltage-gated Potassium channels
- Closing of L-type Ca channels.
- Potassium Efflux.

(0 to -40)

**THE negativity increases due to the potassium ions leaving

- **It should be noted that a hyperpolarized state is necessary for pacemaker channels to become activated.**
- **Without the membrane voltage becoming very negative at the end of phase 3, pacemaker channels remain inactivated, which suppresses pacemaker currents and decreases the slope of phase 4.**
- **This is one reason why cellular hypoxia, which depolarizes the cell and alters phase 3 hyperpolarization, leads to a reduction in pacemaker rate (i.e., produces bradycardia).**

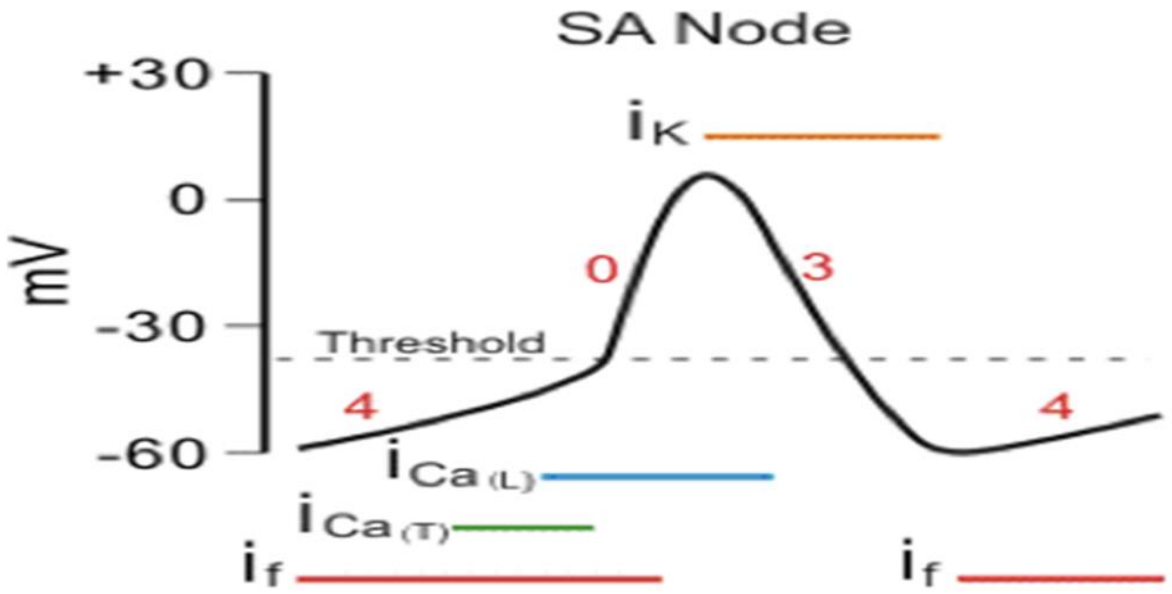
(Hypoxia is a condition in which the body or a region of the body is deprived of adequate oxygen supply at the tissue level or increase in co2 level)

Phase 4:

Slow depolarization due to Na^{+} and Ca^{2+} leak until threshold
Its caused by na+ inward current called i(f)

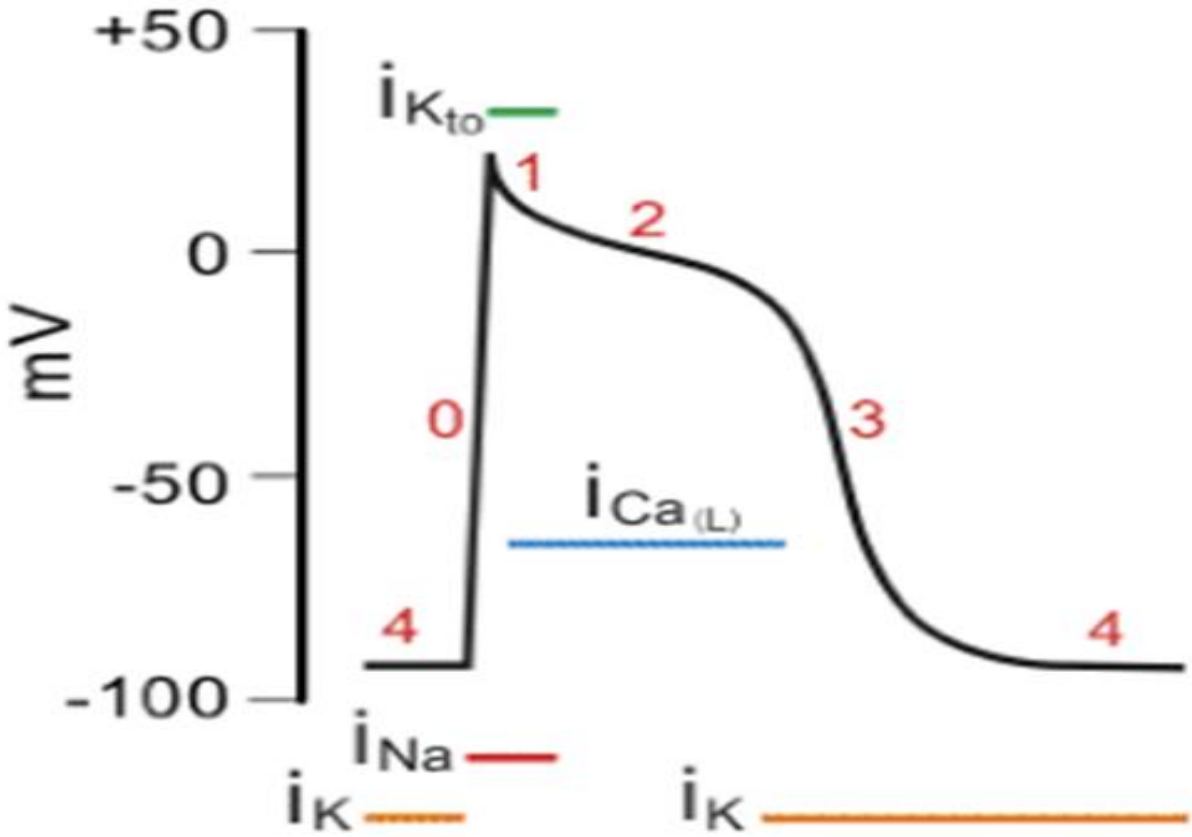
Be careful

in s.a node a.p there aren't phase 1 &2,look at the picture below



Membrane potential of venticular cell

Fast = non-pacemaker cells



- **Phase 4:** Resting membrane potential near the K^+ equilibrium potential.

**Note no kind of threshold to increase +...it's a kind of true
Resting membrane potential .

- **Phase 0:** Depolarizing impulse activates fast Na^+ channels and inactivates K^+ channels. fast and straight line
- **Phase 1:** Transient opening of K^+ channels and Na^+ channels begin to close.

- decreasing + by closing na+ dramatically it makes true repolarization

- The channels of na makes a difference between pacemaker and non pacemaker cells
- **Phase 2 (plateau phase)**: Ca^{2+} channels are open, **key difference between nerve AP.** Positivity inside the cell increase (this phase is responsiple of the length of the AP and the heart beat itself)
- **Phase 3**: Repolarization, Ca^{2+} inactivate and K^+ channels open.

**Fast response (fast depolarization) occur on atrium and ventricular chambers
**Its take a long time due to plateau phase because ca +2 inward
Notes :-myocardium contraction opens a kind of channels not a funny channels eg:- opening l k and dramatically change positivity
**Pacemaker cells are not a part for generate a.p Because there is no true depolarization due to differences of ca+2 channels

**How pacemaker make a regulation of a.p?
Regulation and autonomic system doesn't mean controlling of depolarization and a.p because autonomic system in it isnt like skeletal and nerve cell...

**Regulation of pacemaker with s.a node are:_
1) **sympathetic** (flight and fight)
increase heart rate
Regulation and modification
Depolarized and more rapid depolarization .
2)parasympathetic(rest & digest)
slowing heart rate and contractions
Hyperpolarized and slower depolarization

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كل التوفيق☺