PHYSIOLOGY

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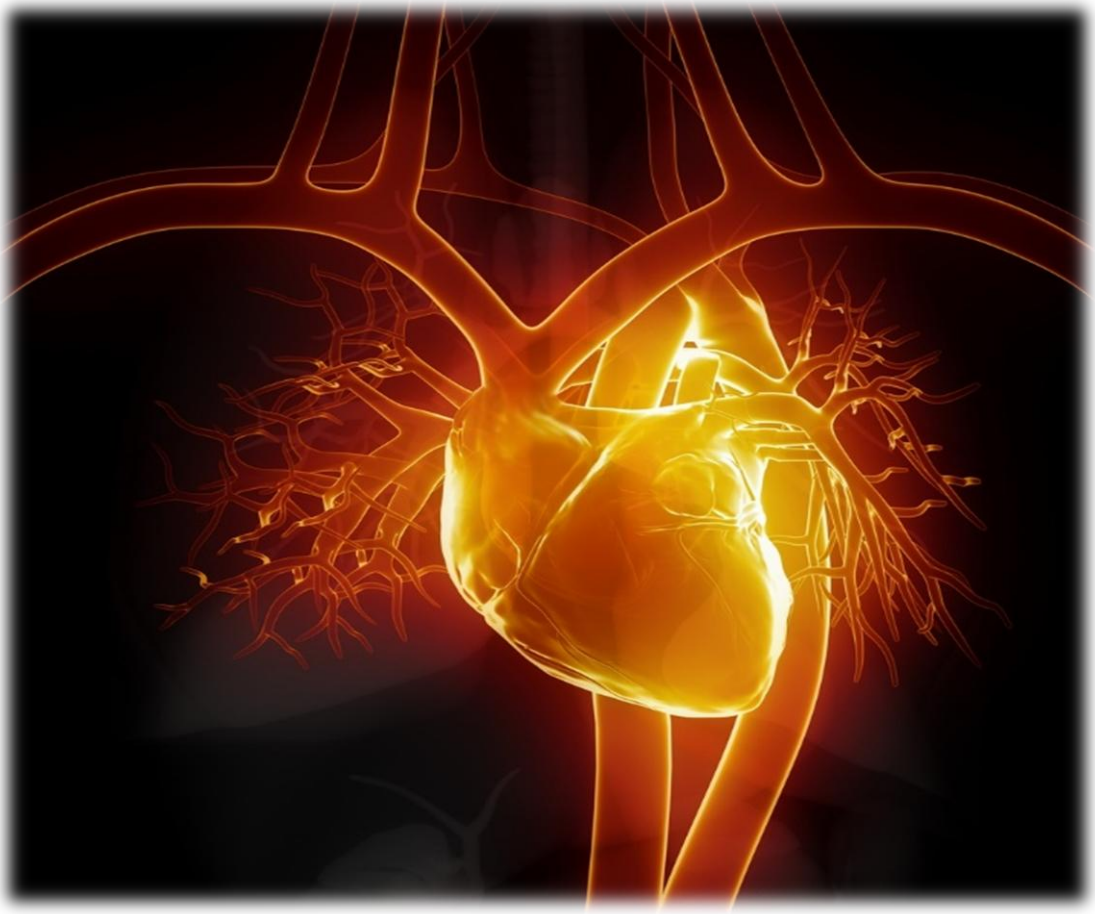
"Introduction to Cardiovascular physiology "



Salam everyone , I did my best to make this sheet clear enough to be easily understood , ☺ let the party begin :P

Introduction:

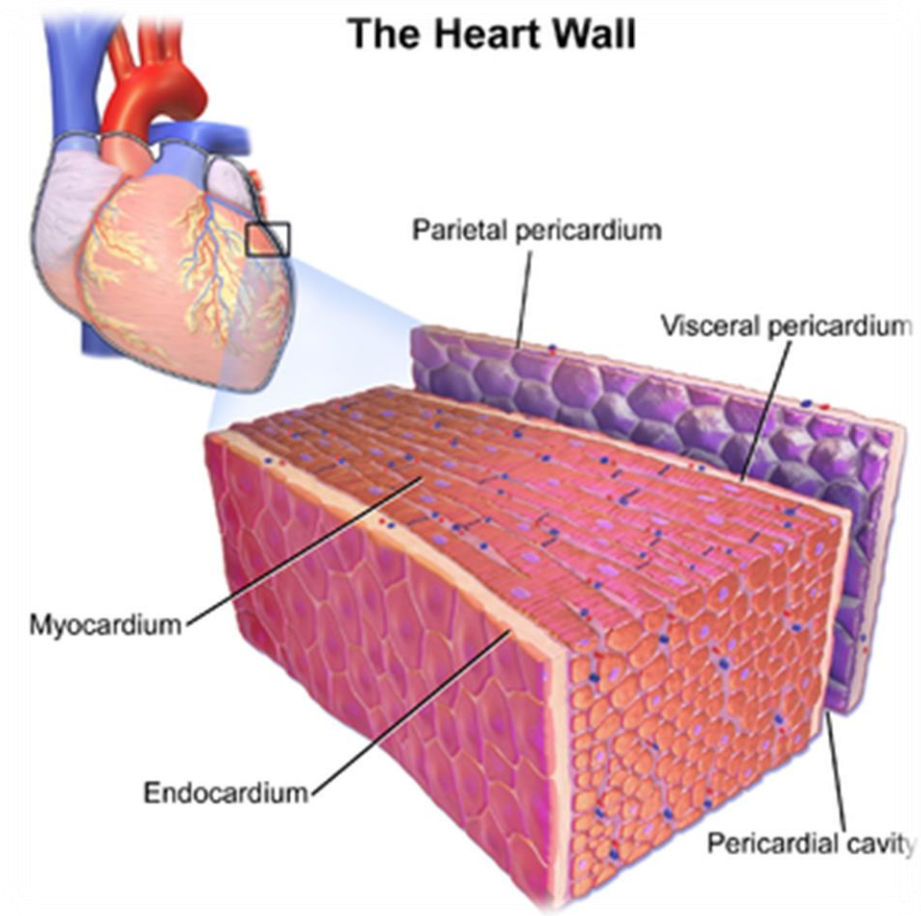
The heart walls are composed primarily of spirally arranged cardiac muscle fibers and have three distinct layers:

■ A thin inner layer, the endothelium, a unique type of epithelial tissue that lines the entire circulatory system

■ A middle layer, the myocardium, which is composed of cardiac muscle and constitutes the bulk of the heart wall (myo means "muscle"; cardia means "heart")

■ A thin external layer, the Pericardium, and it consists of two layers:

Visceral (close to the heart), and Parietal (with the pericardial space in between which contains a serous fluid for protection).

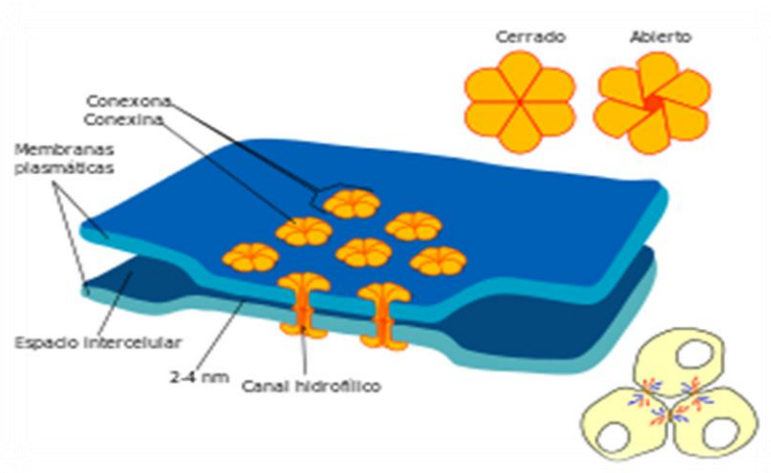


A comparison between Skeletal and Cardiac Muscles:

- Skeletal muscles are spindle in shape and are long since they start from the origin to the insertion. While the cardiac muscle cells are rectangular in shape and smaller.

- Both are striated due to the presence of sarcomeres that contain contractile muscle fibers (proteins). There are four types of contractile proteins:
Myosin forming the thick filaments.
Tropomyosin forming the doubly helical line to which *Actin* "beads" are connected, and *Troponin*. The latter three form the thin filaments.

- Skeletal muscle cells are not connected to each other; motor nerves supply a number of fibers to cause their contraction (a motor unit). While cardiac muscle cells are connected with each other by intercalated disks with gap junctions between them. The gap junctions conduct electricity from one cell to another, forming low resistance areas, causing them to open or close as a response to changes in voltage (voltage-gated channels). When they open the ions move from one cell to another quickly; thus, cardiac muscles are electrically coupled. "دكتورة لا تطلعي هون و هون الله يرضى عليك" Any change (action potential) in one cell spreads into all cells at the same time through the gap junctions. This electrical change (action potential) is followed by a mechanical change (the contraction), and since the cells receive the action potential at the same time, they contract as one unit and the heart will work as a pump. Pathologically, if each cardiac muscle cell contracts by itself (Atrial or Ventricular fibrillation) the heart will not function and ventricular fibrillation will cause death. Gap junctions are hexagonal proteins with an "open" and "closed" conformation.



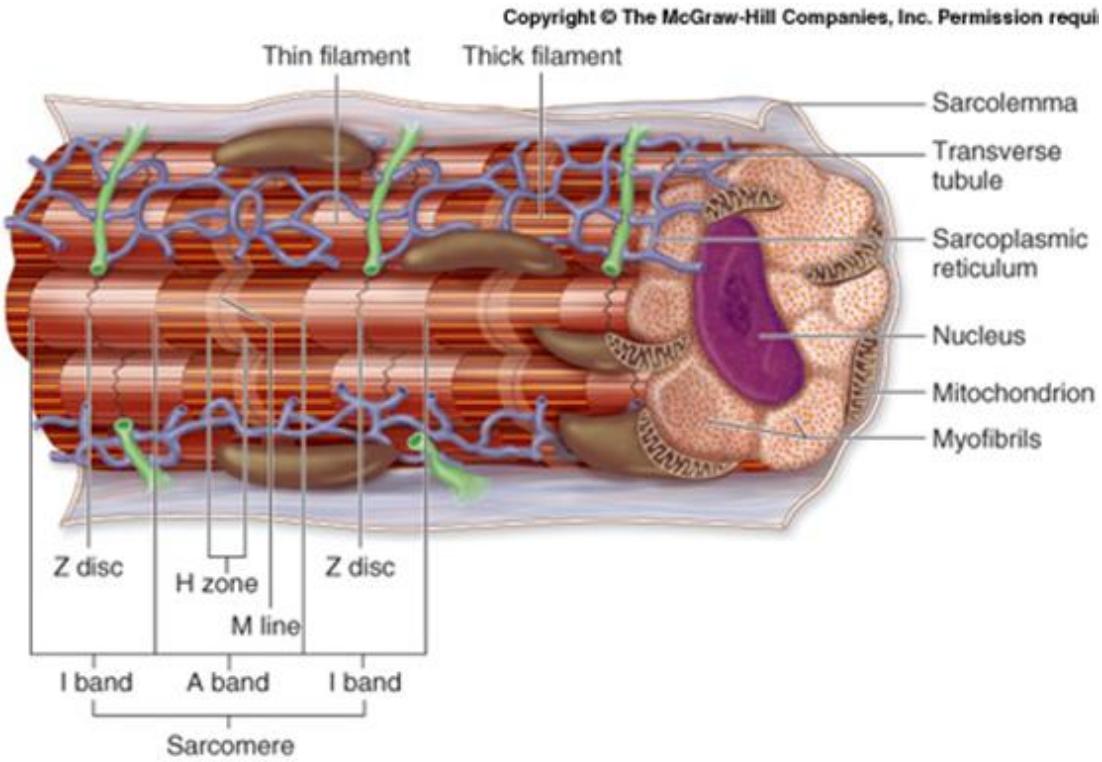
- Skeletal muscles are voluntary, it cannot contract unless it is innervated. While cardiac muscles are involuntary, although it is supplied by the autonomic nervous system (sympathetic and parasympathetic). This innervation of the cardiac muscle is not important for the initiation of cardiac muscle contraction (during cardiac transplants the autonomic supply is cut but the heart is still running). The contraction of cardiac muscle follows (None or All law). " !! اطلعي برا ، شمال و يمين اطلعت اللي دكتورة "

- In the muscle we call:

The plasma membrane :- sarcolemma SL.

The endoplasmic reticulum :- sarcoplasmic reticulum SR.

The cytoplasm :- sarcoplasm.



(b) Cardiac muscle fiber, longitudinal view

- The sarcolemma of cardiac and skeletal muscles have deep invaginations called the T-tubules or transverse tubules. The T-tubules of skeletal muscles are found in the I band, they are also slender and long; so each sarcomere has **two** T-tubules. While in the cardiac muscle, they are wider and shorter and occur at the Z line (disk); so each sarcomere has **one** T-tubule. The sarcomere is the distance between two Z lines. - The sarcoplasmic reticulum (which stores Ca++) is well developed in the skeletal muscle. While in the

cardiac muscle, it is less developed so the cell doesn't store enough Ca++ for its contraction and needs an extra source of Ca+ from outside (extracellular fluid around cells – interstitial fluid). That's why during heart transplants, the heart is put into a solution with Calcium.

- The cardiac muscle contracts all the time. This means it needs a lot of energy, that's why it has lots of mitochondria to supply ATP compared to skeletal muscles that, on the other hand, have much more nuclei.

Action potential of skeletal muscle:

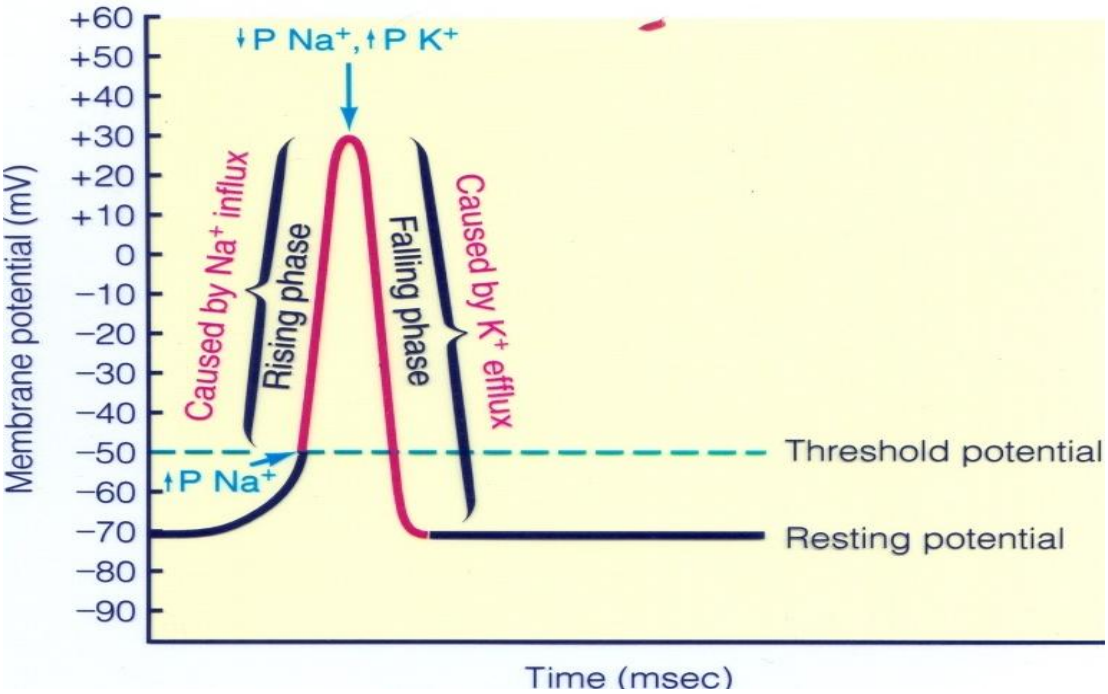
- Resting stage due to K+ diffusion starts at -70.

- Slow depolarization till it reaches the threshold.

- Fast depolarization (firing stage) due to the quick opening of Na+ voltage gated channels. (It tries to reach the equilibrium potential for Na+ {+61} but it doesn't get there because other ions are involved).

- Repolarization (falling stage) due to the opening of K+ channels.

- Very short (between .1 mSec to 10 mSec maximum).



Action potential of cardiac muscle:

- The resting membrane potential is -90mV (more negative). Phase 4.

- Fast depolarization is due to the opening of Na+ voltage gated channels. Phase 0.

(There is an increase in the permeability of Na+ and a decrease in the permeability of K+) ,

Note :

" اكبر ها اكثر ؟ بمزح بس نقطة مهمة كتييير "

" *The decrease of the Potassium level to less than what it was during the resting stage* is important.. But why? Because if that didn't happen, Potassium will diffuse to the outside, and Calcium will take its place. Therefore, that way, a positive went out & a positive went in, there's no benefit in that! As a result, there will be no Plateau. "

- Partial repolarization is due to the opening of transient K+ and Cl- specialized channels. Phase 1.

Again, the increase in Potassium permeability during Phase 0 and 1 is very important in order to maintain the Plateau.

- Plateau (maintaining depolarization) is due to slow opening of Ca+ channels. Phase 2. (This induces the release of Ca+ from the SR. This process plays the main role in contraction).

- Repolarization is due to the opening of K+ voltage gated channels. Phase 3.

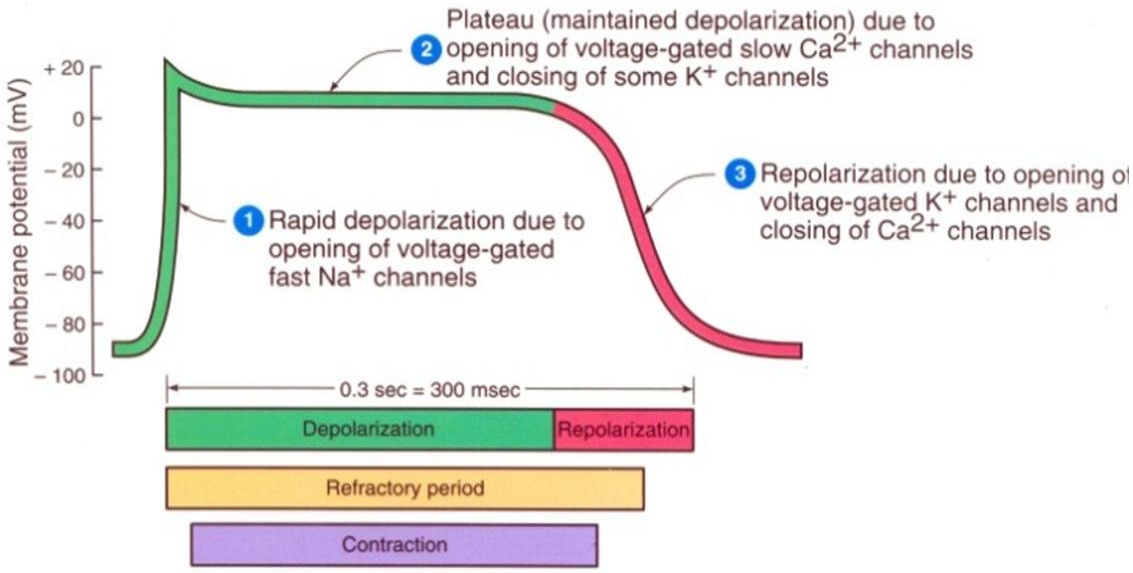
- Return to the resting stage by the Na-K pump for the rearrangement of ions. Phase 4.

-So, how many phases do we have?

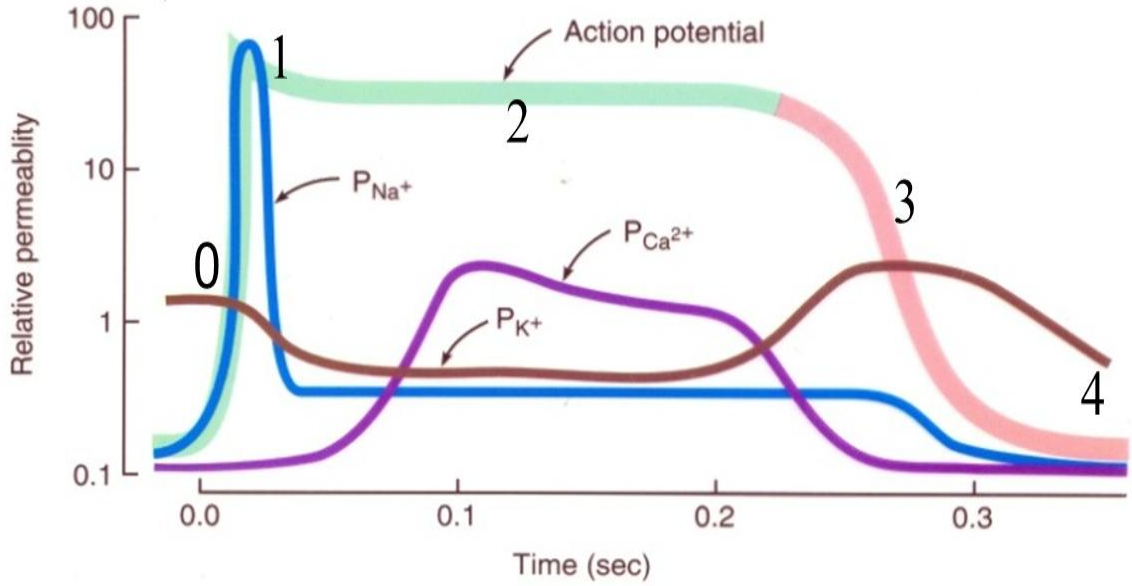
" عمر , يا عمر , كم واحد عندنا ؟ "

Yeah , 5 phases " 0,1,2,3,4 "

- This action potential is very long, occurs for about 200 – 400 mSec (normally 300) , thanks to the long refractory period (an absolute refractory period from the beginning to half of the repolarization stage where the muscle cannot contract, and a relative refractory after it where the muscle may contract to a stronger stimulus)



(a) Action potential, refractory period, and contraction



(b) Membrane permeability (P) changes

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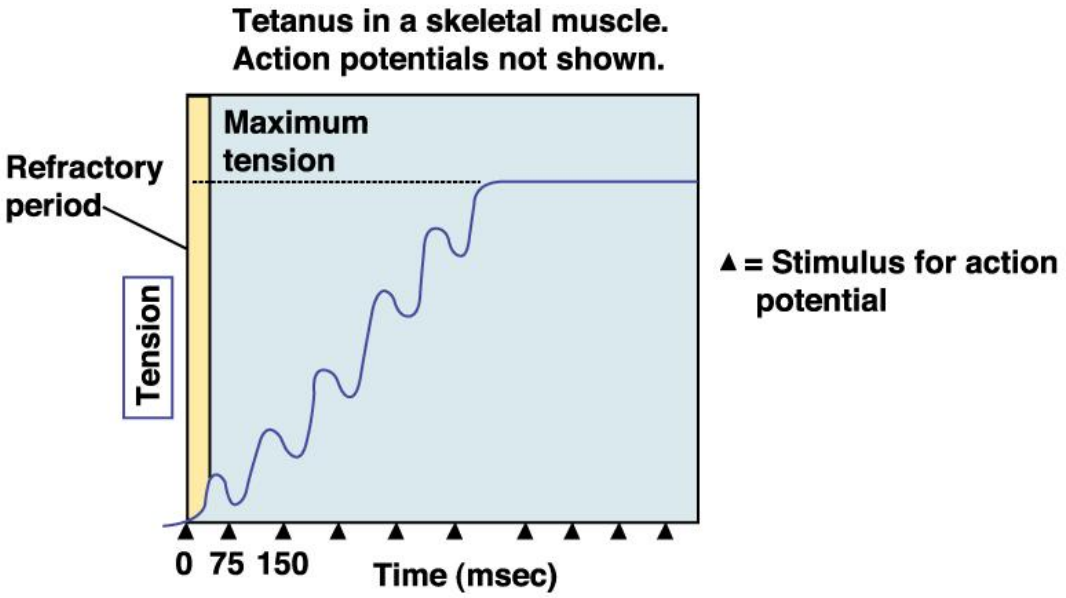
The Contraction and Tetanisation:

In the skeletal action potential:

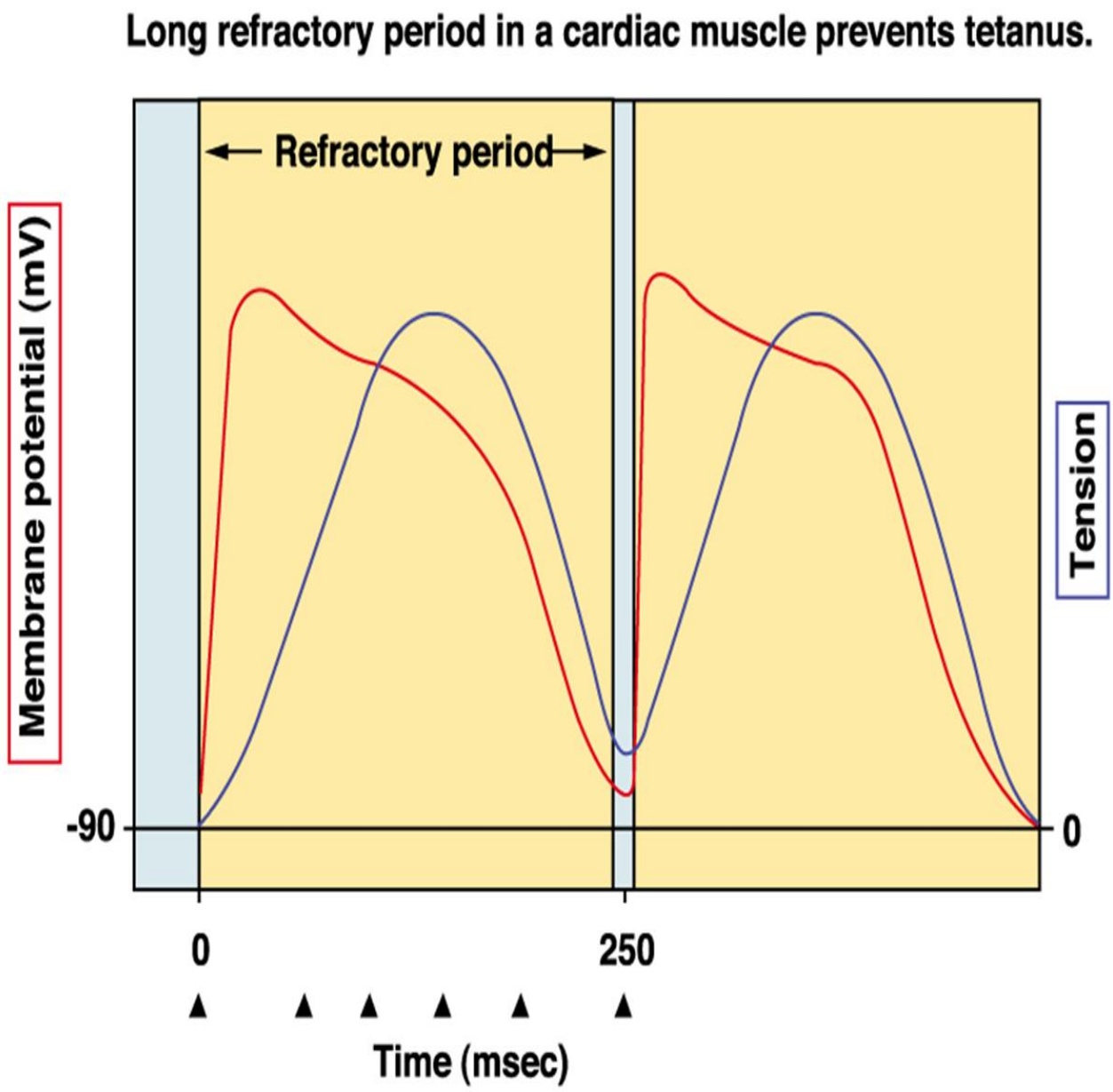
Because of the short action potential, if there's another stimuli, a new action potential and another contraction will start in the relative refractory period of first action potential. This is called tetanus or spasm (summation of contractions with no relaxation).

(Relative refractory period: the last half of the repolarization phase until the action potential has ended).



In the cardiac action potential: ‣When the Heart is given an Action Potential, it will NOT give the Muscle Tetanus no matter how strong the Action Potential is, but the question is Why?

That is **because** it has a VERY long Absolute Refractory Period.



Summary of the phases :-

Phase 0 : Depolarization (Na+ influx) .

Phase 1: Partial repolarization (K+ efflux and Cl- influx) .

Phase 2 : Plateau (slow Ca+ influx) .

Phase 3 : Fast repolarization (K+ efflux) .

Phase 4 : Resting membrane potential .

Quiz time..

1. In which phase does the number of positive charges entering exceed the number of positive charges leaving:

A. phase 2.

B. phase 0.

C. phase 4.

D. phase 1.

E. phase 3.

2. The low resistance pathway between myocardial cells that allow for the spread of action potentials is:

A. mitochondria.

B. intercalated discs.

C. t tubules.

D. gap junction.

E. sacroplasmic reticulum.

3. Which phase coincides with diastole (relax):

A. phase 2.

B. phase 0.

C. phase 4.

D. phase 1.

E. phase 3.

4. During which phase is the conductance to Ca+ the greatest:

A. phase 2.

B. phase 0.

C. phase 4.

D. phase 1.

E. phase 3.

5. During which phase is the membrane potential closest to the K+ equilibrium potential:

A. phase 2.

B. phase 0.

C. phase 4.

D. phase 1.

E. phase 3.

Husain physiology ☺