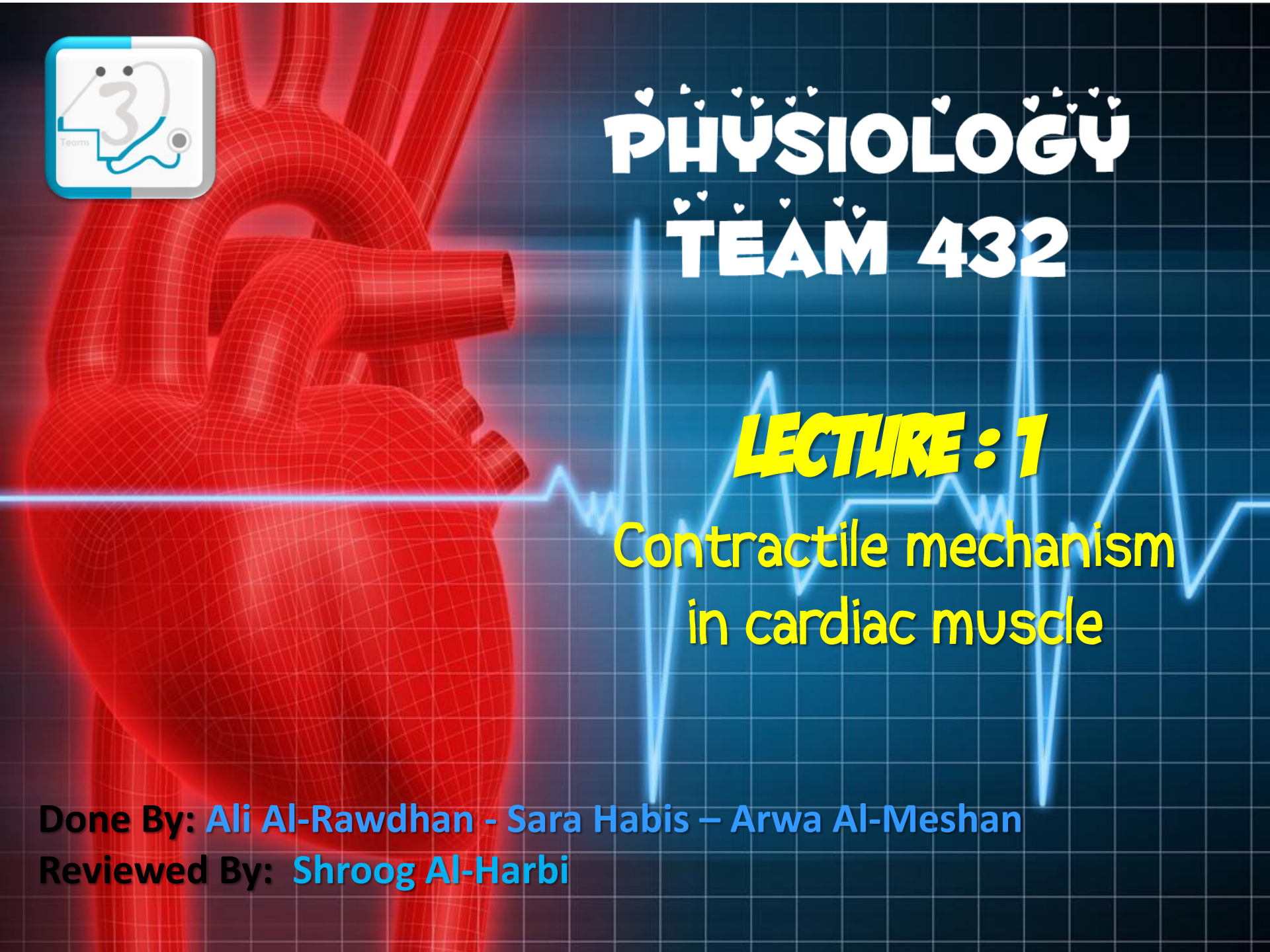

PHYSIOLOGY TEAM 432

LECTURE : 1

Contractile mechanism in cardiac muscle

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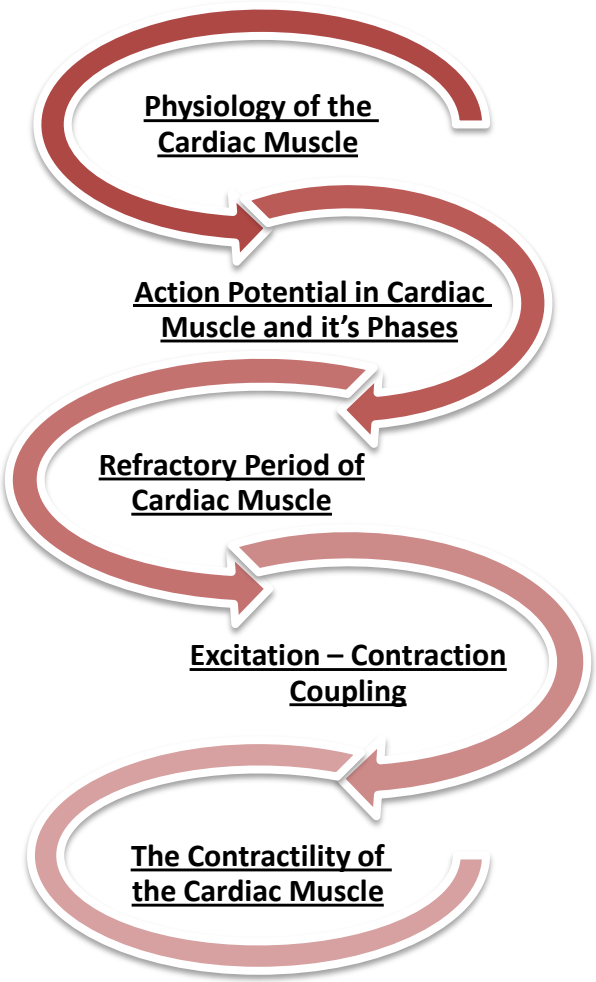
Reviewed By: Shroog Al-Harbi

OBJECTIVES

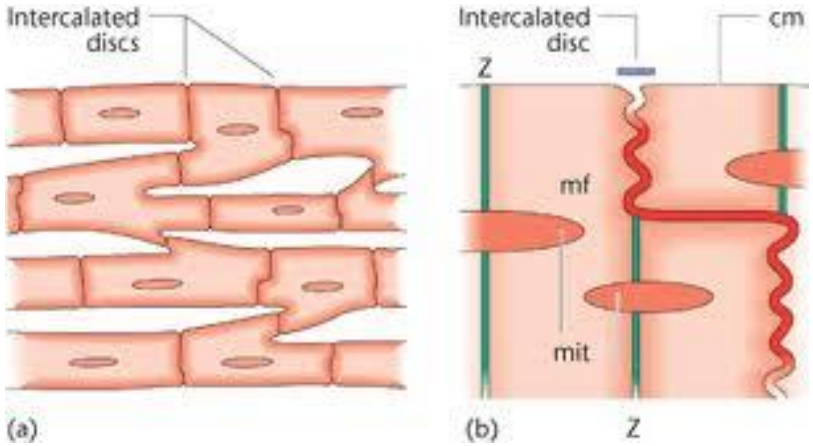
- Define cardiac muscle contractility
- Understand the phases of cardiac action potential and the ionic bases
- Discuss the role of calcium ions in the regulation of cardiac muscle function
- Describe the mechanism of excitation contraction coupling
- Factors affecting cardiac contractility

MIND MAP


Physiology of the Cardiac Muscle
Action Potential in Cardiac Muscle and it's Phases
Refractory Period of Cardiac Muscle
Excitation – Contraction Coupling
The Contractility of the Cardiac Muscle

Intercalated discs:

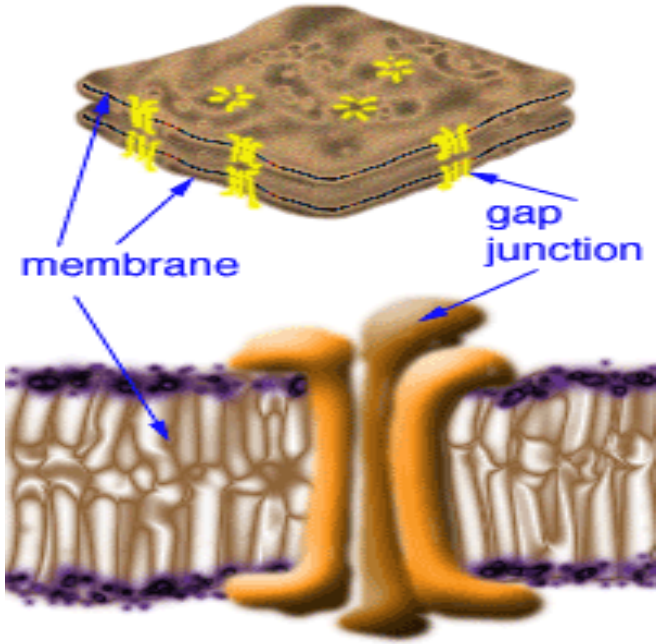
cell membranes, separate individual cardiac muscle cells from one another.



Gap Junctions:

trans-membrane channel proteins, connecting the cytoplasm of the cells , allow :

- **free diffusion of ions.**
- **Action potentials travel from one cardiac muscle cell to another.**



Cardiac Muscle is a *Syncytium:

Stimulation of a single muscle fiber:

1. **the action potential spreads from cell to cell through the gap junctions.**
2. **contraction of all the muscle fibers.**

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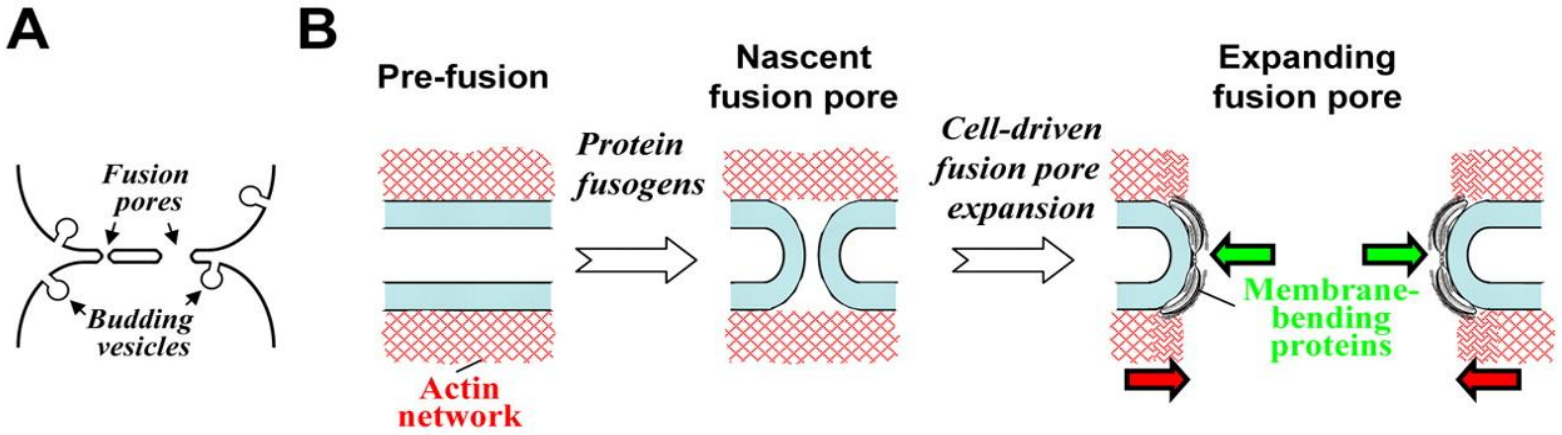
*Syncytium : cells that are interconnected by specialized membrane with gap junctions, as seen in the heart muscle cells and certain smooth muscle cells, which are synchronized electrically in an action potential.

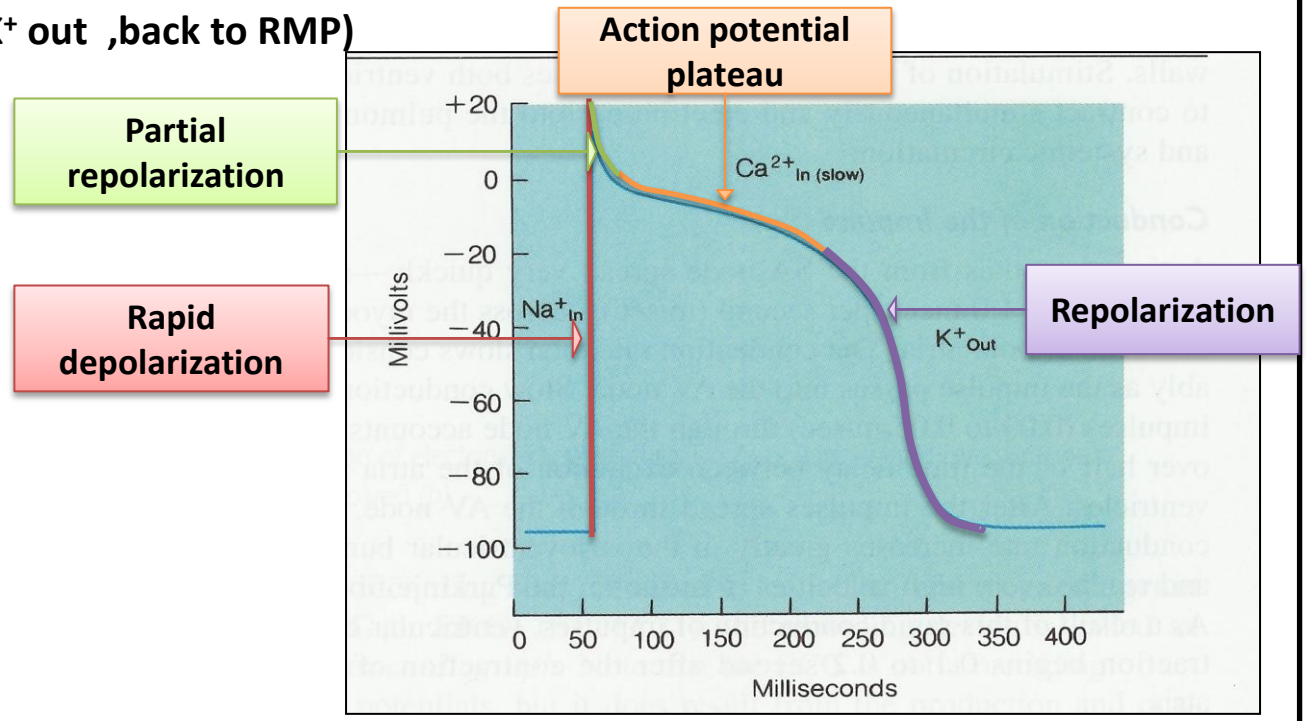


Action Potential in Cardiac Muscle and it's Phases

Resting membrane potential -85 mV :(the charge mean the different between concentration of ions outside and inside the cell membrane, means more –ve ions inside the membrane or in other word the +ve ions are less inside the membrane).

Phases of Action Potential in Cardiac Muscle:

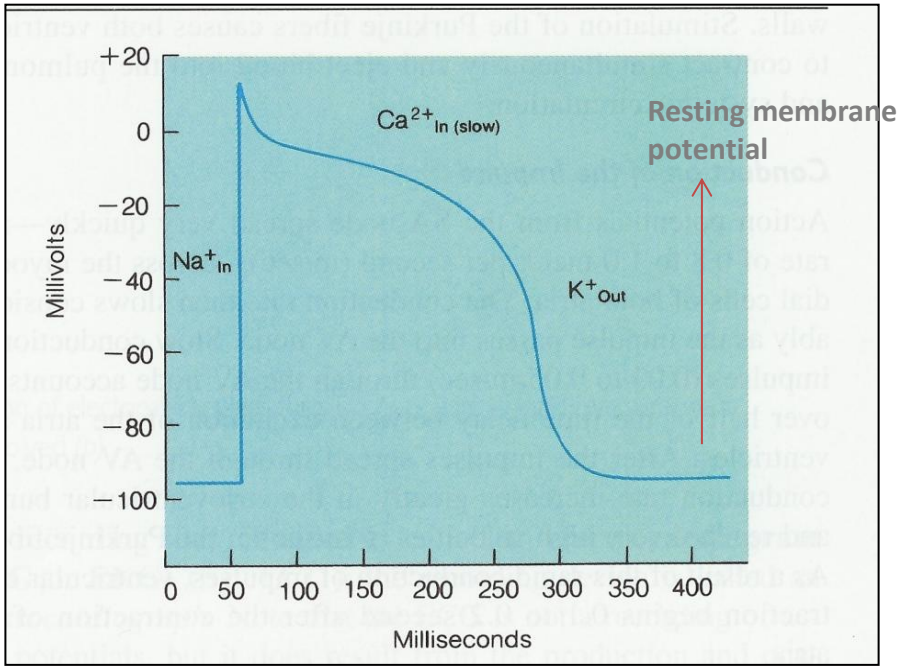
1. Rapid depolarization (Fast sodium channels Na^+ in ,+20 mV)
2. Partial repolarization (K^+ out ,5-10 mV)
3. Action potential plateau (Slow calcium channels Ca^{2+} in ,0 mV)
4. Repolarization (K^+ out ,back to RMP)



- Resting membrane potential -85 mV.

It is very important here to know which ion takes the upper hand in each phase

Phases of cardiac Action Potential	Ionic changes
Rapid depolarization (+20 mV)	Fast sodium channels Na^+ in
Partial repolarization (5-10mV)	K^+ out
Action potential plateau (0 mV)	Slow calcium channels Ca^{2+} in
Repolarization (back to RMP)	K^+ out

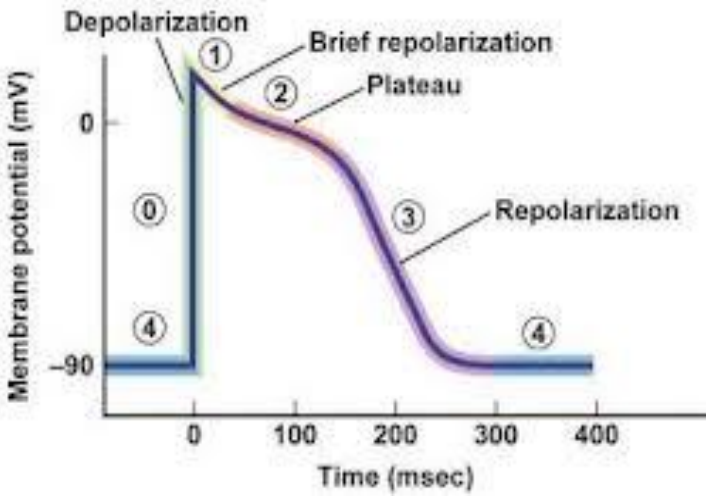


Action Potential in Cardiac Muscle and it's Phases

What causes the Plateau (means steady) **in the Action Potential?**

1. Slow calcium channels: slow to open & remain open
   → Large quantity of calcium ions flow to the interior (in) of the cardiac muscle fiber.
   → Maintains prolonged period of depolarization .
   → Causing the plateau in the action potential.
2. *Decreased* permeability of the cardiac muscle membrane for potassium ions that result from the excess calcium influx.
   →decrease outflux of potassium ions during the action potential plateau.

Note:
(The Action Potential in the cardiac muscle is longer than AP in the skeletal muscle because of the Plateau phase prolonged period of depolarization, and this also cause the shape of the AP curve in cardiac muscle which is not like the AP spike in skeletal muscle)



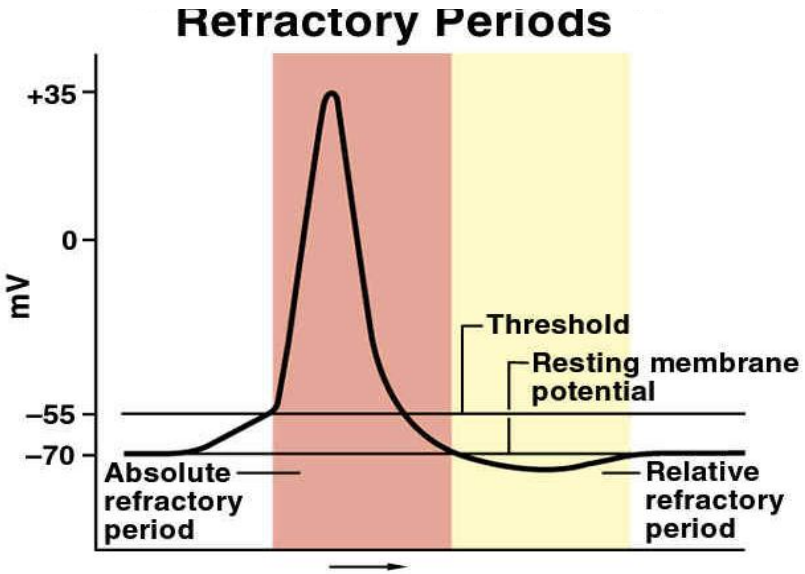
Refractory Period of Cardiac Muscle

What causes Refractory Period ?

- **Cardiac muscle is refractory to re-stimulation during the action potential.**
- **The refractory period of the heart:**

is the interval of time during which a normal cardiac impulse cannot re-excite an already excited area of cardiac muscle.

❖ The interval that when I give a stimulus into stimulated, excited or contracting cardiac muscle, it won't respond = Refractory Period



Duration in seconds is not important

Refractory Period of Cardiac Muscle

Divides into two periods:

Absolute refractory period

*Cardiac muscle cannot be excited while it is contracting .

*importance : to let the blood pool inside the heart from all over the body to start another cycle.

*Long ARP.

*Time: depolarization and 2/3 repolarization.

*Duration: 0.25- 0.3 sec.

Relative refractory period

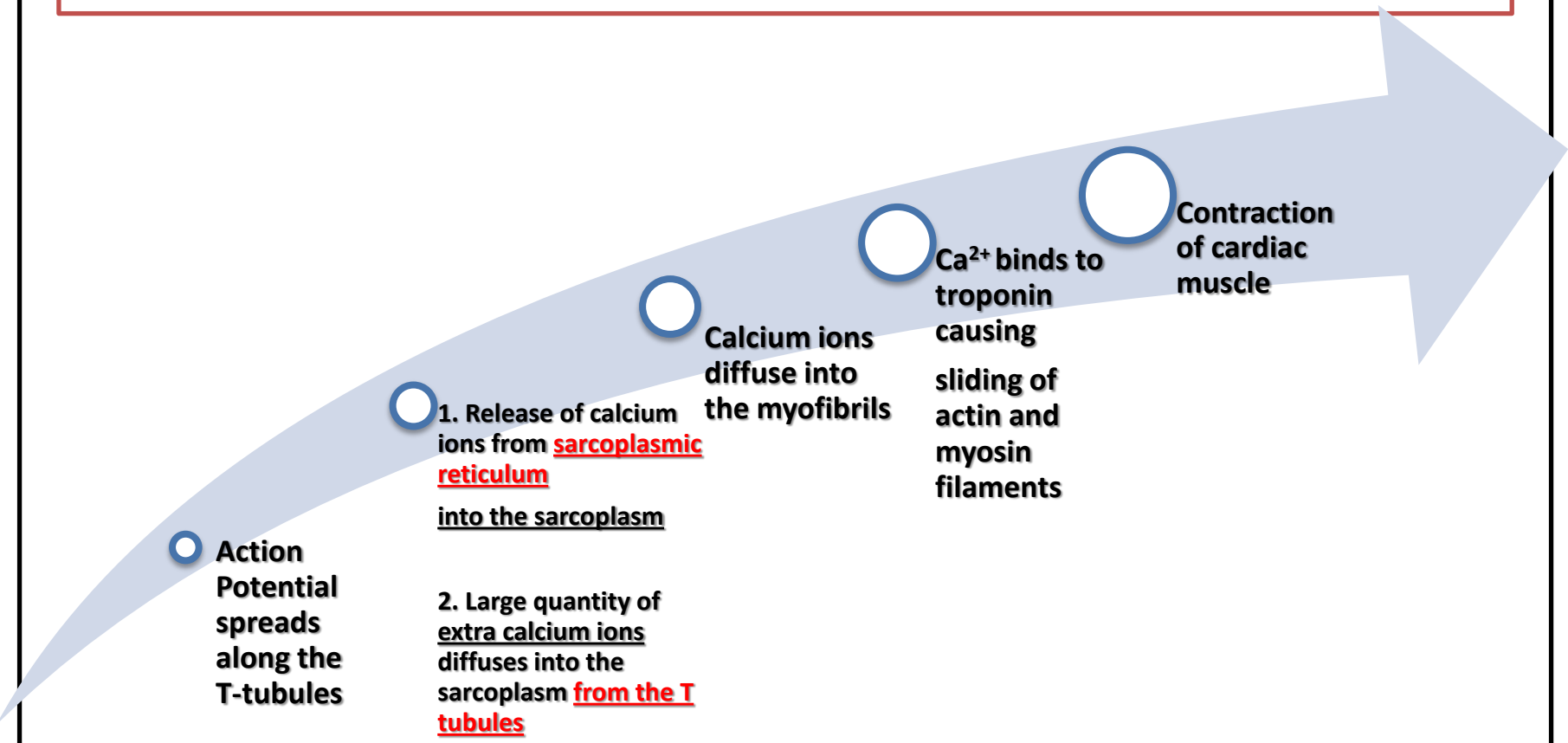
*Cardiac muscle can be excited by strong stimulus.

*Time: the last 1/3 of repolarization.

*Duration: 0.05 sec.

Excitation – Contraction Coupling

- is the mechanism by which the action potential causes muscle contraction
- Action potential spreads to the interior of the cardiac muscle fiber along the transverse (T) tubules



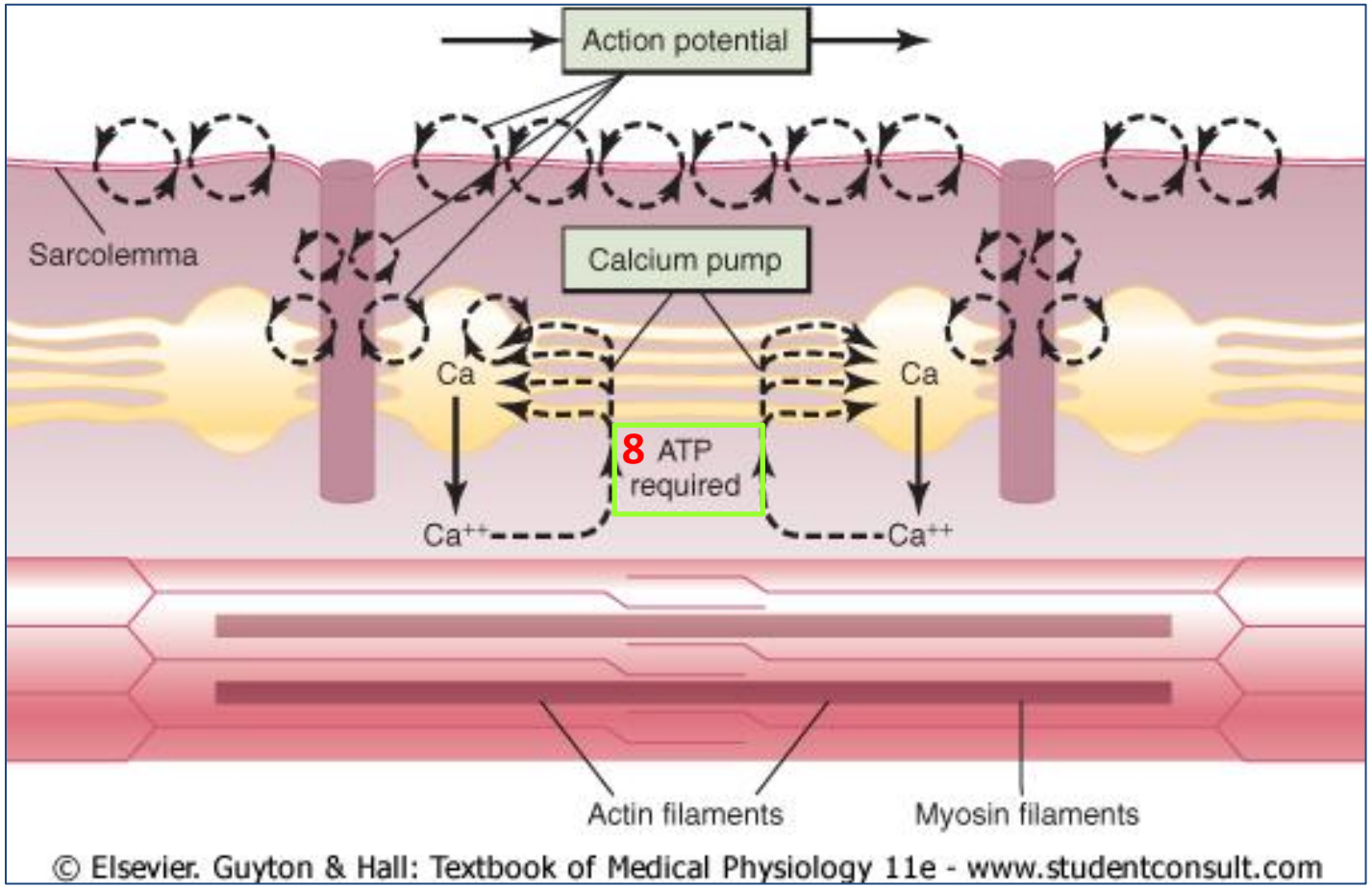
Excitation – Contraction Coupling

- At the end of the Plateau of the action potential
  → **calcium ions are pumped back into the sarcoplasmic reticulum and the T-tubules → contraction ends (repolarization)**
- The T tubules of cardiac muscle have a diameter 5 times as great as that of the skeletal muscle tubules.
- The strength of contraction of cardiac muscle **depends** to a great extent on the concentration of calcium ions in the extracellular fluids

Excitation-contraction coupling in the muscle

- Each contraction involves the hydrolysis of an ATP molecule for the process of contraction and sliding mechanism.
- **Cardiac muscle are continually contracting and require substantial amounts of energy (Active Process)**
- The energy is derived from ATP generated by **oxidative phosphorylation** in the mitochondria.
- The myocytes contain large numbers of **mitochondria**.

Excitation-contraction coupling in the muscle



The Contractilityof the Cardiac Muscle

- **Contractility is the force of contraction of the heart** & it is essential for the pumping action of the heart.

- **Ionotropic effect: mechanism that affect the contractility.**

  - ***Positive Ionotropic Effects: factors that increase the cardiac contractility***
    1. ***Sympathetic stimulation***
    2. ***Calcium ions***

  - ***Negative Ionotropic Effects: factors that decrease the cardiac contractility***
    1. ***Parasympathetic stimulation***
    2. ***Acetylcholine***
    3. ***Vagal stimulation***

*أسئلة تم اقتباسها من منتدى تجمع قامت بكتابتها العضو (Flame) مفيدة جدًا ^_^

*The depolarization phase of the cardiac muscle action potential occurs when:
a- voltage-gated Ca2+ ion channels open
b- voltage-gated K+ ion channels open
c- voltage-gated Na+ ion channels open
d- both b and c

answer is : c

*Action potentials pass rapidly from one cardiac muscle cell to another because of:
a-intercalated disks and numerous gap junctions
b- large nerves with branches going to each cardiac muscle cell
c- the large voltage of cardiac action potentials.
d- the plateau phase of the action potential.
e- open Ca2+ channels.

Answer is : a

*Which of these statements concerning cardiac muscle is correct?
a- Cardiac muscle has more sarcoplasmic reticulum than skeletal muscle.
b- Cardiac muscle has a prolonged period of slow repolarization called the plateau phase.
c- Cardiac muscle has a shorter refractory period than skeletal muscle
d- Depolarization of cardiac muscle occurs when K+ and Na+ diffuse into the cell.
e- all of these are correct

answer is : b

*Which of these conditions occurs in the cardiac muscle cell during the final repolarization phase?
a- voltage-gated Ca2+ ion channels are open.
b- voltage-gated K+ ion channels are open
c- voltage-gated Na+ ion channels are open
d- all of these

answer is : b

*Which of these conditions occur in the cardiac muscle cell during the plateau phase?
a- voltage-gated Ca2+ ion channels are open
b- voltage-gated K+ ion channels are open
c- voltage-gated Ca2+ ion channels are closed
d- a+b

answer is: d

*Early repolarization of cardiac muscle cells occurs when:
a- voltage-gated Ca2+ ion channels open
b- voltage-gated K+ ion channels open
c- voltage-gated Na+ ion channels close
d-both b and c

answer is : d

SUMMARY

- Gap junctions is important in action potential spreads and cardiac muscle Syncytium
- Resting membrane potential -85 mV
- Phases of Action Potential in Cardiac Muscle:
  - ✓ Rapid depolarization (Na^+ in ,+20 mV)
  - ✓ Partial repolarization (K^+ out ,5-10 mV)
  - ✓ Action potential plateau (Ca^{2+} in ,0 mV)
  - ✓ Repolarization (K^+ out , back to RMP)
- Slow calcium channels causes the Plateau phase in the Action Potential
- Refractory period a duration of the action potential when the cardiac muscle is not responding to the regular stimuli.
- Excitation – Contraction Coupling Converting the action potential to a contraction.
- Positive Ionotropic Effects: factors that increase the cardiac contractility.
- Negative Ionotropic Effects: factors that decrease the cardiac contractility.

THE END

If there are any problems or suggestions
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THANK YOU