




-  Very important
-  Extra information
-  Terms

Physiology

OF THE CARDIOVASCULAR SYSTEM

Contractile Mechanism of Cardiac Muscle

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

Histology of cardiac muscles

- **Intercalated discs** : cell membrane separate cardiac muscles from each other.
- **Gap junction** : transmembranous channels connecting the cytoplasm of the cells, thus :
 - 1) Allow ions to diffuse from cell to another.
 - 2) Action potentials travel from one cardiac muscle cell to another.

Because of that , the heart muscles are very connected that if one cell is excited , action potential will spread to all the cells , thus cardiac muscles are **Syncytium** :

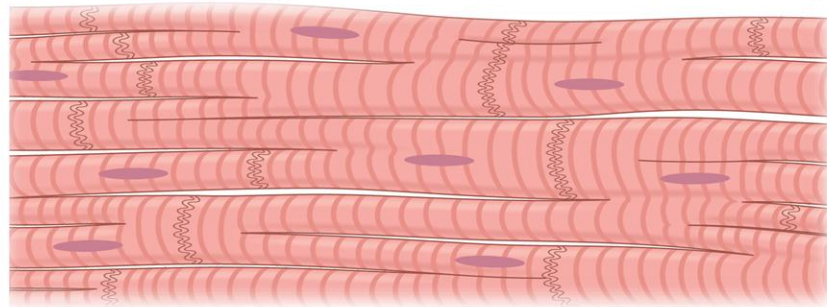
Stimulation of a single muscle fiber



AP spread through gap junction



contraction of all the muscles fibers



Action potential in cardiac muscles

- Resting membrane potential = **-90 mV** .
- Duration of cardiac action potential = **0.4** Seconds.

Phase	Ionic changes	Value
<ul style="list-style-type: none"> • Phase 0 : Depolarization “Rapid depolarization” 	<ul style="list-style-type: none"> • Fast Na+ channel open , Na+ flow <u>into</u> the cell. 	+20 mV
<ul style="list-style-type: none"> • Phase 1 : Initial “partial” repolarization 	<ul style="list-style-type: none"> • K+ flow out the cell 	5-10 mv
<ul style="list-style-type: none"> • Phase 2 : Action potential Plateau 	<ul style="list-style-type: none"> • Slow calcium channels <u>open</u> • Ca⁺⁺ moving in slowly. • membrane permeability to K+ will decrease 	0 mv
<ul style="list-style-type: none"> • Phase 3 : Rapid repolarization 	<ul style="list-style-type: none"> • Ca+ channels <u>close</u> • K+ outflow . • <u>End of plateau</u> . 	-
<ul style="list-style-type: none"> • Phase 4 : Resting membrane potential 	back to normal level	-90 mV

Action potential in cardiac muscles

* What causes the plateau in cardiac action potential ?

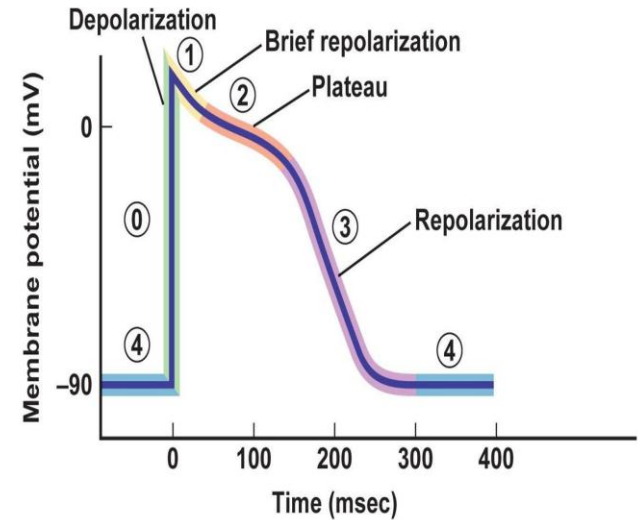
1- Slow calcium channels :

slow to open & remain open for several tenths of a second → Large quantity of calcium ions flow to the interior of the cardiac muscle fiber → Maintains prolonged period of depolarization → Causing the plateau in the action potential.

2- decrease permeability of K^+ :

decrease outflux of potassium ions during the action potential plateau

[When the slow calcium channels close at the end of the plateau the membrane permeability for potassium ions increases rapidly, and this return the membrane potential to its resting level, thus ending the action potential].



When there is a stimulus : [Phases of AP of cardiac muscle]

- **Rapid depolarization** = +20 mv.
(why is it +ve ? because of Na^+ influx through the sodium channels)
عندما تصبح القيمة +20 تغلق قنوات الصوديوم ويتوقف عن التدفق إلى داخل الخلية

- **Partial repolarization** = +5 to +10 mv. (K^+ outflux)
خسارة البوتاسيوم تتسبب في انحدار القيمة من +20 إلى +5 ومنها للصفحة

- **Action potential plateau** "only in the cardiac muscle" = ZERO
Plateau means constant , it is not losing or gaining any charges.
slow calcium channels : عندما تصبح القيمة صفراً ، هنا تُفتح بوابات الكالسيوم وتسمى :
 K^+ is going out, while calcium is going in "slowly"

Why is it constant ? لأن الكالسيوم يحتوي على شحنتين موجبتين بينما البوتاسيوم يحتوي على شحنة واحدة سالبة بالتالي يقوم الكالسيوم بتعويض النقص.

Note : if they asked "what is the cause of plateau phase?"
your answer should be: **Calcium channels**

- **Repolarization :**

عندما تبدأ هذه المرحلة تتدفق أيونات البوتاسيوم للخارج ونعود إلى نقطة الـ Resting

EXTRA

Refractory period

➤ **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

Refractory period of cardiac muscle

Absolute refractory period

- Cardiac muscle cannot be excited while it is contracting (so, cannot be tetanized*).

- No AP can be initiated

0.25 – 0.30 sec [LONG]

- Begins with the Upstroke of the AP [depolarization and 2/3 repolarization]

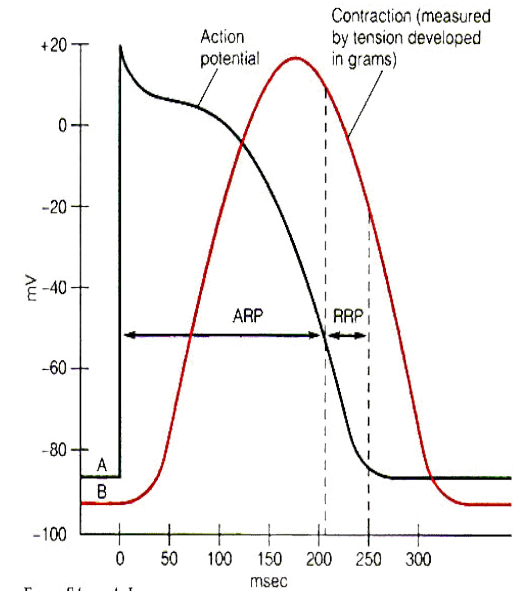
Relative refractory period

- Cardiac muscle can be excited by strong stimulus

- Action potential can be elicited
- The result is premature contraction

0.05 sec [SHORT]

- immediately after Absolute Refractory Period [Repolarization]



Fox, Stuart Ira.
Human Physiology, 5th
1996, WCB publishers

* تشنج

- Refractory period** : whatever stimulus come to the cell, it will not response.

- There is 2 types of refractory period : **Absolute & Relative**

- Absolute** : whatever the strength of the stimulus, the cell will not respond.

- Almost all the AP in the heart is occupied by Absolute refractory period. وتكمن الأهمية هنا في منع تشنج عضلة القلب

Excitation – Contraction Coupling

➤ Excitation – Contraction Coupling:

is the mechanism by which the action potential causes muscle contraction.

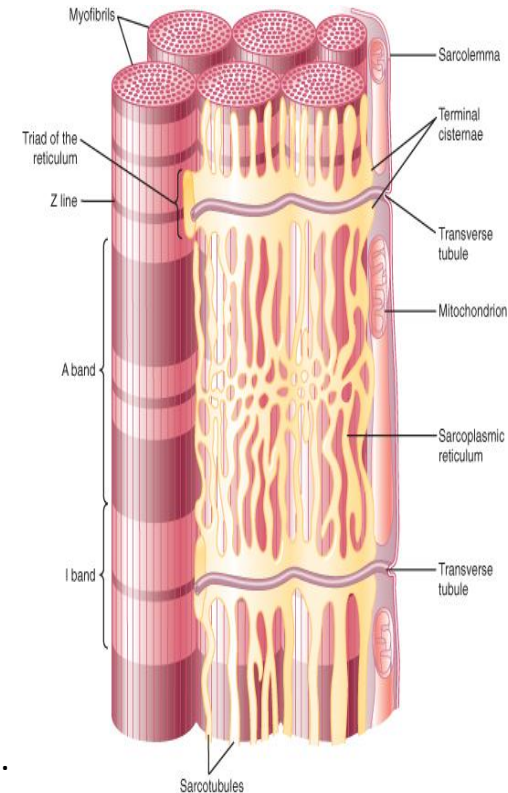
1- Spread of AP to the interior of the cardiac muscle fiber along the transverse (T) tubules.

2- Release of calcium from Sarcoplasmic reticulum into the sarcoplasm

3- Calcium ions diffuse to myofibrils

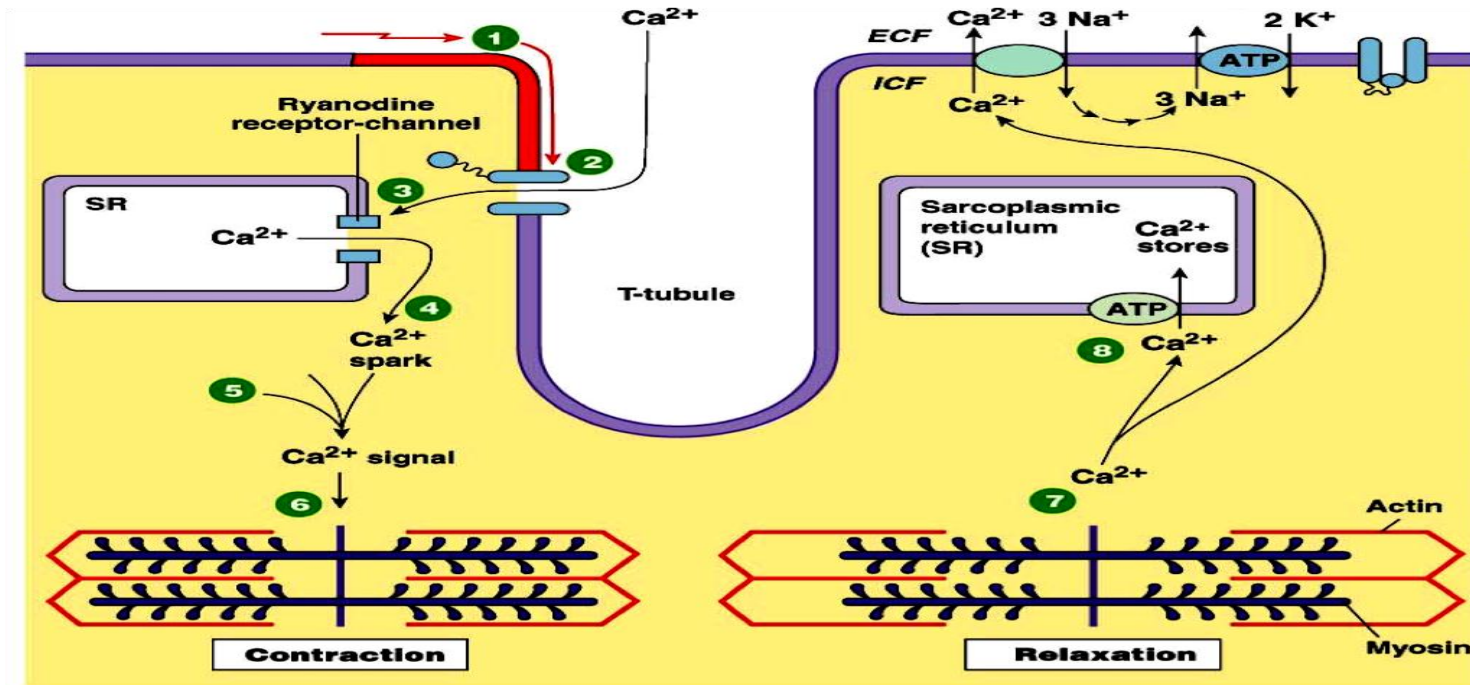
4 - Ca^{2+} binds to troponin causing sliding of actin and myosin filaments

5- Contraction of cardiac muscle

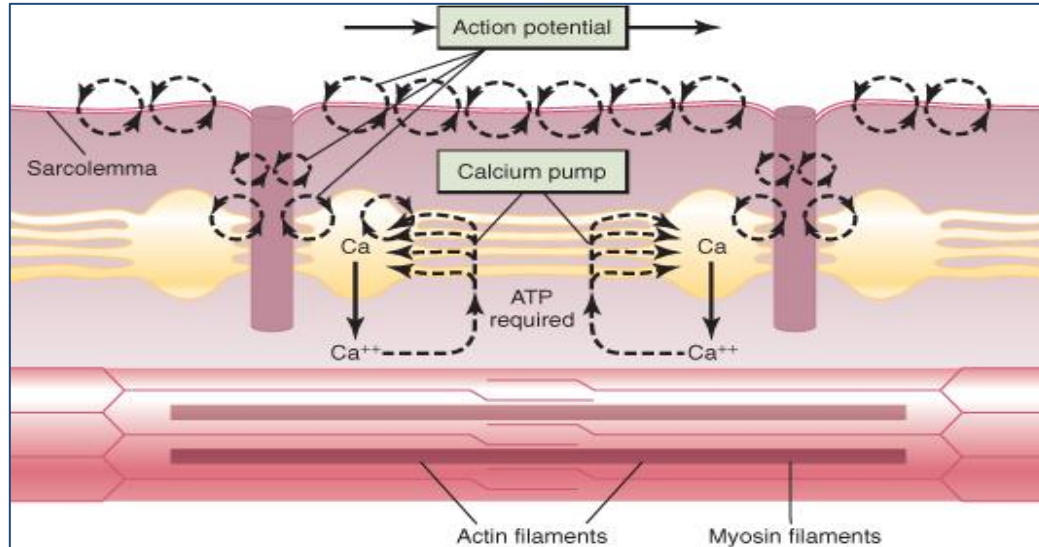


➤ At the end of the Plateau of the action potential :

- calcium ions are pumped back into the sarcoplasmic reticulum and the T-tubules.
- contraction ends (repolarization)



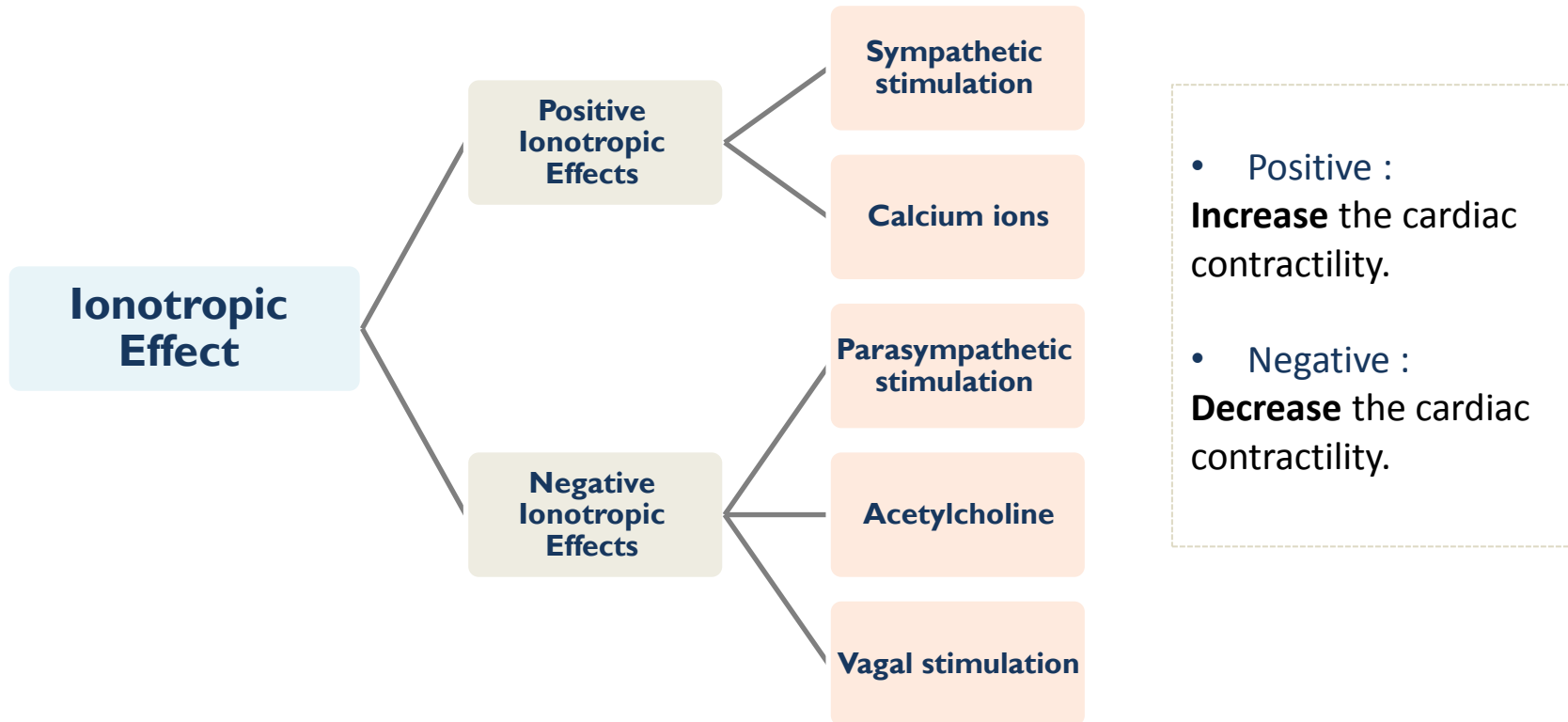
- The T tubules of cardiac muscle have a diameter **5 times** as great as that of the skeletal muscle tubules.
- The strength of contraction of cardiac muscle **depends** to a great extent on the **concentration of calcium ions** in the extracellular fluids.



- 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
- The energy is derived from ATP generated by **oxidative phosphorylation** in the **mitochondria**.
- **The myocytes contain large numbers of mitochondria.**

The Contractility of the Cardiac Muscle

- **Contractility** is the force of contraction of the heart
- It is essential for the pumping action of the heart



Physiology

OF THE CARDIOVASCULAR SYSTEM

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- Monera Alayuni
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- Nouf Alabdulkarim
- Nora Albusayes
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