جامعة الملك سعود
King Saud University

MED438
KING SAUD UNIVERSITY

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Lecture 1
Cardiac Contractility

- Red: important
- Black: in male / female slides
- Pink: in female slides only
- Blue: in male slides only
- Gray: extra information

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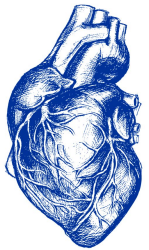

Physiology
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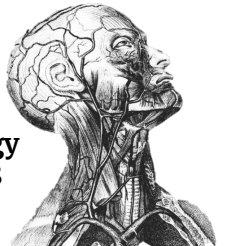


Objectives:

- Define cardiac muscle contractility.
- Describe the mechanism of excitation-contraction coupling.
- Understand the mechanism of isovolumetric and isometric contraction.
- Factors affecting cardiac contractility.
- Describe the action potential of the cardiac muscle and its components.
- Define the refractory period and the excitation-contraction coupling.

Contractility of the cardiac muscle

- ***Contractility*** is the force of contraction for a given fiber length
- When stimulated, the cardiac muscle fiber contracts and this contraction determines the pumping power of the heart.

Type of contractility	
Isometric	**Isotonic**
• Muscle increases tension • Muscle is not shortened • Ventricular pressure open aortic and pulmonary valves	• Muscle is shortened. • Muscle has the same tension • Volume of heart diminishes & ventricle pumps blood to the body

Iso = same tonic = tone (tension) metric = distance (shortening)

Type 1: Contractile cells

There are two major types of cells:
contractile and conducting cells (specialized excitatory and conducting cells); Contractile cells are either atrial muscles or ventricular muscles. so we have 3 types of muscles in total

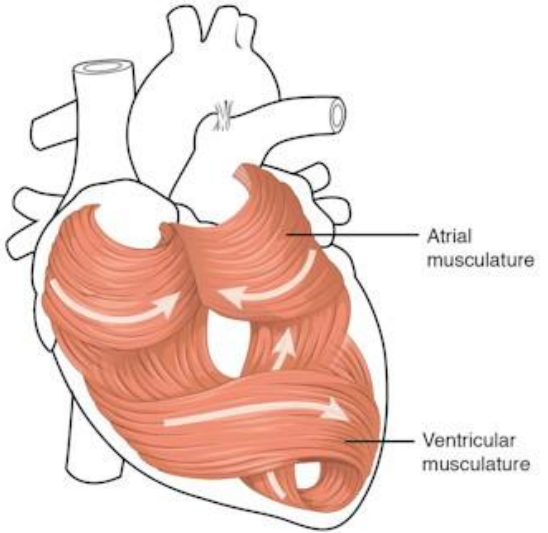
Characteristics

- Cylindrical, branching, striated cells
- They make up 99% of the cardiac muscle
- Mononucleated cells (central and oval nuclei)
- Abundant mitochondria (40% of cell volume) (produce energy)
- Less abundant sarcoplasmic reticulum (store calcium)
- Sarcolemma (cell membrane) has specialized Ca++ voltage gated channels.
- They are separated by **intercalated discs**, which contain **gap junctions** and **desmosomes** that allow:
  - Free diffusion of ions (they have a very low electrical resistance)
  - Action potential to travel between cells

Cardiac contractile filaments share a lot of similarities with skeletal muscles in the sense that they both have myosin, actin, and troponin.

Functional Syncytium

- Stimulation of a single atrial muscle fiber causes an action potential to rapidly travel to all atrial cells through the gap junctions, leading to contraction of all the muscle fibers. This means that the cardiac muscles act as a functional syncitum AND follow the all or none principle.
- The same principle applies to ventricular muscle fibers, but NEVER both at the same time.
- Cardiac muscle forms two syncytia:
  1. Atria syncytium (between atria)
  2. Ventricular syncytium (between ventricles)
- The atrium and ventricles are separated by a fibrous barrier that prevents the passage of impulses between the two muscles
- Action potential is conducted between them by "A-V bundle"
- This division of the cardiac muscles allows atria to contract before ventricles (this increases the effectiveness of cardiac pumping)



Type 2: Conducting cells (Autorhythmic)

They're specialized cells containing less contractile fibrils (do not contract) responsible for the electrical stimulation of the heart. They conduct AP faster than contractile cells.

Physiological features of the heart:

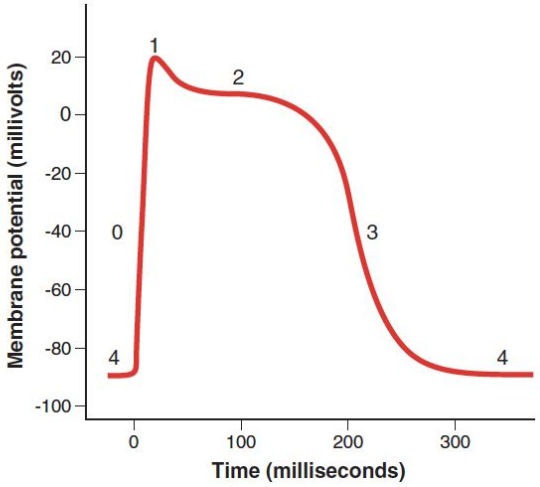
- Self-stimulating (automaticity)
- Rhythmicity (generate impulses in a repetitive manner)
- Conductivity (conducts electrical current throughout the heart)
- Excitability (provide an excitatory system to the heart)
- Contractility

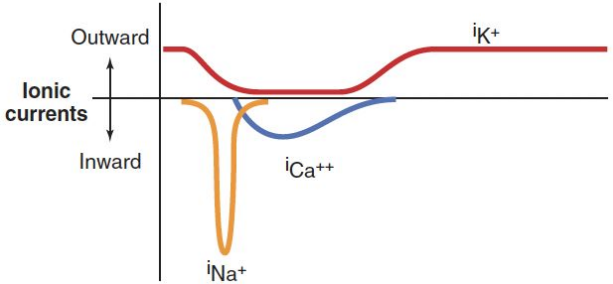
Action potential of Cardiac Muscles

- The resting membrane potential is -90mV
- The duration of the action potential is 300-400 ms
- It has 5 phases:

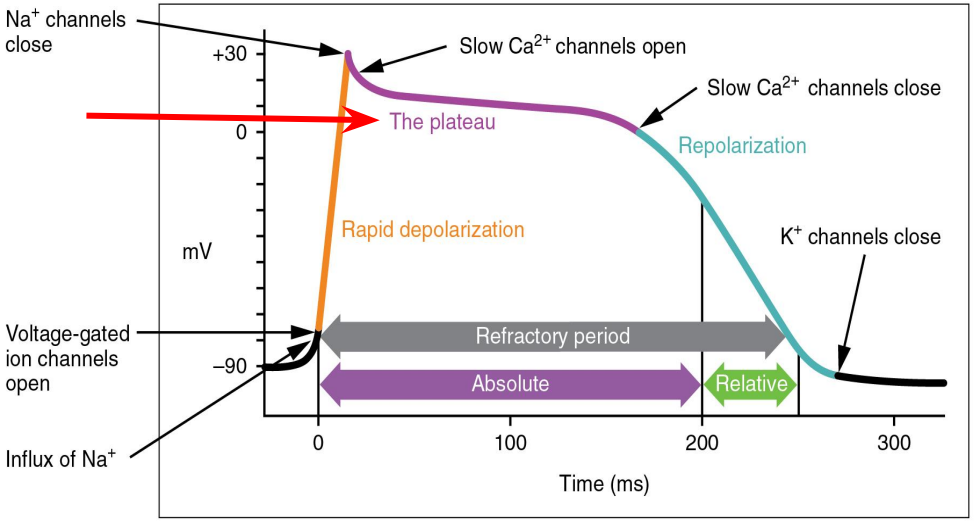
Magnitude is 110 mV

Phase	Description	Potential
0	Rapid depolarization caused by Na+ voltage gated channel (fast channels) opening allowing **Na+ influx**	+20 mV
1	Rapid partial repolarization due to **K+ efflux** and closure of Na+ gates	5-10 mV
2	Plateau, flat portion of the curve due to **prolonged Ca++ influx**. Balanced by efflux of an equal amount of K+. It's 0.2 s in atria and 0.3 s in ventricles	0 mV
3	Rapid repolarization due to **K+ efflux** and closure of Ca++ gates	-
4	Membrane goes back to **resting membrane potential** and Na+/K+ pump remove excess ions	-90 mV





Causes of the Plateau Phase During AP



The plateau phase (phase 2) is caused by two main processes:

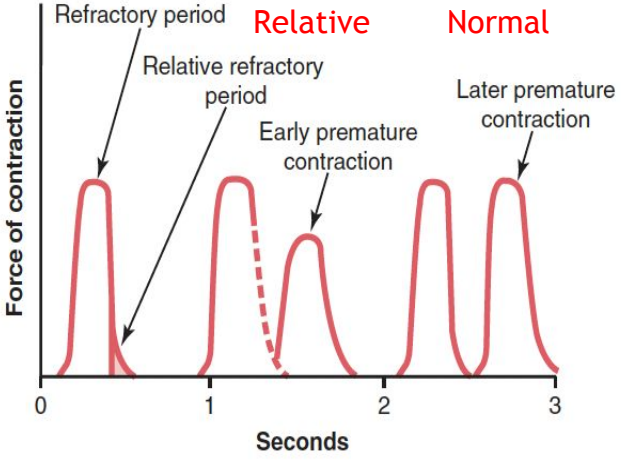
1. **Slow Ca++ channels (L-type calcium channel)** pumping Ca++ to prolong depolarization.
2. Decreased permeability of **K+ voltage gated channels** to delay repolarization

At the end of the plateau, Ca++ channels close and Ka+ permeability increases.

Refractory period of cardiac AP

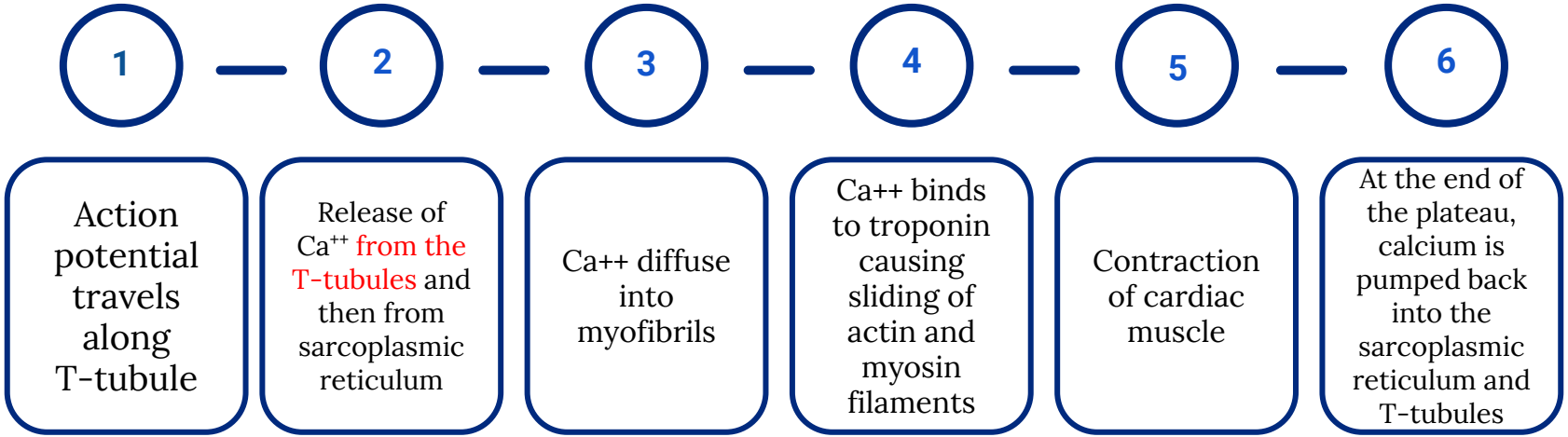
Refractory period is the interval in which a normal cardiac impulse cannot re-excite an excited area (contracted) and it lasts almost as long as the entire muscle contraction.
Significance: prevent tetanus (prolonged spasm) and summation, which may stop the circulation

Types of refractory period		
Type	**Absolute**	**Relative**
Description	Muscle cannot be stimulated Due to the complete depolarization	Muscle can be stimulated by a strong stimulus Producing Extra-systole
Time	Phases 0, 1, 2 and 2/3 of 3	1/3 of phase 3
Occupation	Systole and early diastole	Middle of diastole
Duration	Long (0.25-0.3 s)	Short (0.05 in V and 0.03 in A)



Excitation-contraction coupling

Excitation-contraction coupling is the mechanism in which AP causes muscle contraction.



- T-tubules have 5 times the diameter compared to skeletal muscles
- Strength of contraction depends on Ca++ in the extracellular fluid
- Cardiac muscles need substantial amount of ATP by deriving it from oxidative phosphorylation (contains many mitochondria)

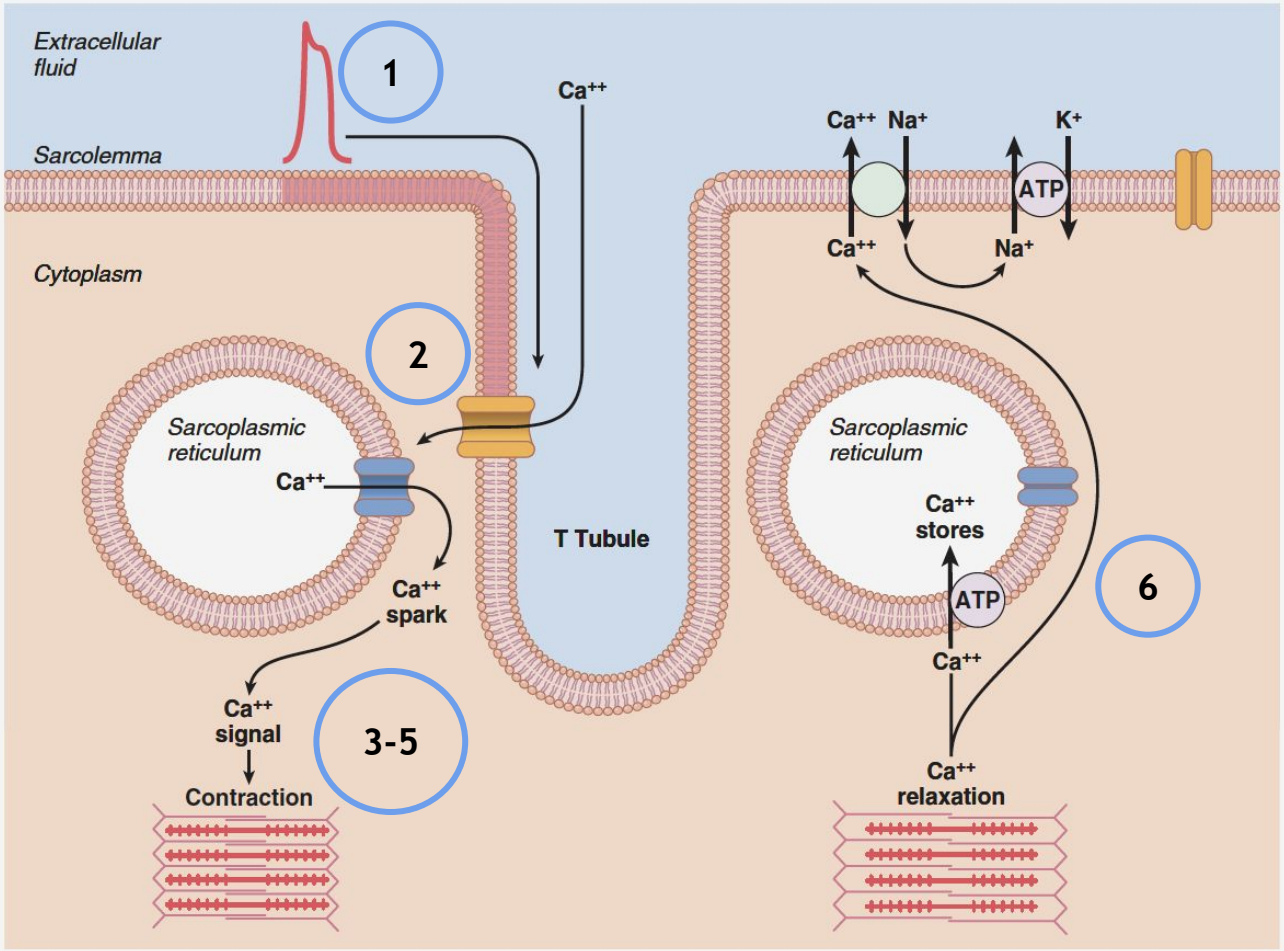


Figure 9-6. Mechanisms of excitation-contraction coupling and relaxation in cardiac muscle. ATP, adenosine triphosphate.

Female slides

Factors affecting cardiac contractility

- **Inotropic effect:** mechanism that affects cardiac <u>contractility</u>
  - Chronotropic effect: affects heart rate
  - Dromotropic effect: affects the conduction of electrical impulses through the myocardium

Factors	Positive inotropic effect	Negative inotropic effect
Nerves	Sympathetic	Parasympathetic (Vagus) (only atria)
Oxygen	-	Hypoxia
Ions	Calcium (Ca++)	Potassium (K+)
Physical	Warming & exercise	Cooling
Hormonal & chemical	• Digoxin, Digitalis • Adrenaline & noradrenaline • Alkalosis • Ca++ • Caffeine	• Beta blockers • Ach • Acidosis • Ca++ channel blockers • Bacterial toxins (e.g. diphtheria)

Factors affecting cardiac contractility

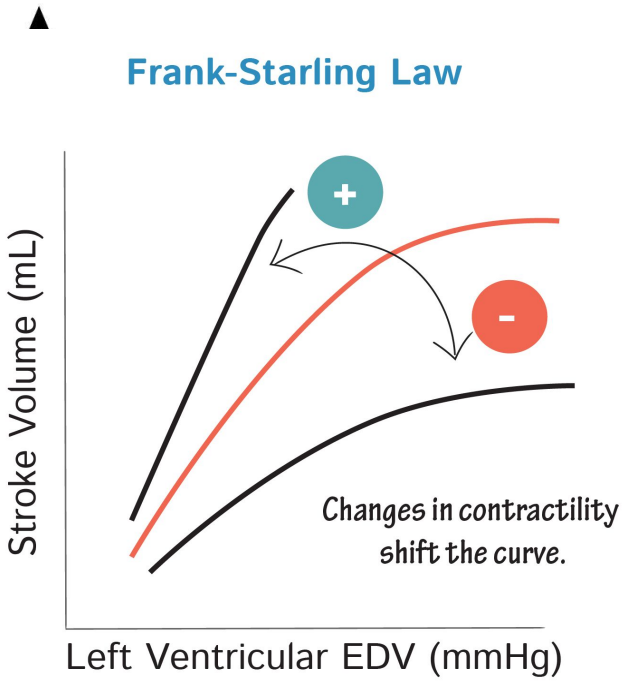
Region affected	Sympathetic nerve effects	Parasympathetic nerve effects
SA node	• Increase diastolic depolarization rate • Increase cardiac rate	• Decrease diastolic depolarization rate • Decrease cardiac rate
AV node	Increase conduction rate	Decrease conduction rate
Atrial muscle	Increase strength of conduction	Decrease strength of conduction
Ventricular muscle	Increase strength of contraction	No effect

Female slides

Mechanical factors affecting inotropy

- **Starling's law of the heart** states that the force of contraction (tension) is proportional to the initial length of the cardiac muscle (EDV) within physiological limits.

- In other words, when the myocardium is filled with blood it stretches significantly which will increase the force of contraction. (Directly proportional)



Quiz

1. Which of these contractions shorten the muscles and preserve its tension?

A. Isotonic
B. Isovolumic
C. Isometric
D. Isotension

2. Which of these is TRUE regarding contractile cells?

A. Less abundant mitochondria
B. Abundant calcium inside the cell
C. Less abundant sarcoplasmic reticulum
D. Mononucleated circular nuclei

3. Which of these is a difference between skeletal and cardiac contraction mechanism?

A. Spread of action potential muscle cells
B. Release of Ca++ from the cisternae
C. Ca++ binding to troponin to form the cross-bridge
D. Diffusion of Ca++ through T-tubule

4. Which of the following is considered a cause of the plateau phase?

A. Release of Ca++ to prolong repolarization
B. Release of Ca++ to slow depolarization
C. Decreased K+ permeability to slow repolarization
D. Decreased K+ permeability to slow depolarization

5. Which of these best describes Starling's Law?

A. Physical factor that increases heart's inotropy
B. Proportionality of stroke volume to EDV
C. Accomodation of cardiac muscle to arterial flow
D. Dependence of initial length to ESV

SAQ:

1- Explain what happens in the excitation-contraction coupling process.

Slide 10

2- Define contractility, and mention its different types.

Slide 3

Answers: A - C - D - C - B - B

Leaders

Sedra Elsirawani Abdulrahman Alhawas

Members

- Lama AlZamil
- Arwa AlEmam
- Noura AlTurki
- Ghada AlSadhan
- Nouf AlShammari
- Nouf AlHumaidhi
- Taibah AlZaid
- Ajeed AlRashoud
- Reem AlGarni
- Raghad AlKhashan
- Leen AlMazroa
- Nouran Arnous
- Maha AlNahdi
- Badr Almuhanna
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- Omar Aldosari
- Omar Alghadir
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