Physiology Team 434

Contractile Mechanism in Cardiac Muscle

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Color index

- Important
- Further Explanation

Only in Boys' Slides

Only in Girls' Slides

Explained in **Guyton Chapter 9**

Objectives

- ✧ Define cardiac muscle contractility
- ✧ Describe the mechanism of excitation-contraction coupling.
- ✧ Understand the mechanism of isovolumetric and isometric contraction.
- ✧ Factors affecting cardiac contractility.

✓ Girls'

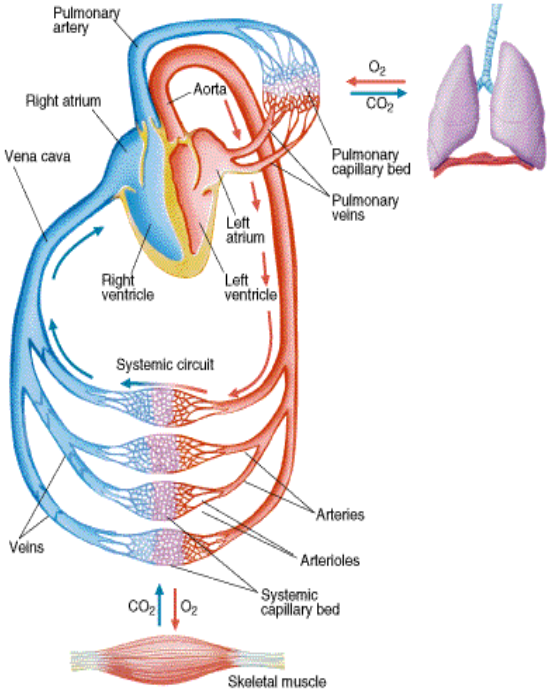
- ✧ Understand the phases of cardiac action potential and the ionic bases
- ✧ Discuss the role of calcium ions in the regulation of cardiac muscle function

✓ Boys'

- ✧ Describe the general features and overall design of the cardiovascular system.
- ✧ Describe how the heart accomplishes its function as the central pump of the CVS.
- ✧ Outline the structure of a typical myocyte.
- ✧ Describe excitation-contraction coupling in the heart.
- ✧ Discuss sliding-filament mechanism of contraction.
- ✧ Describe cardiac muscle mechanics.
- ✧ Outline the types of contractions in skeletal and cardiac muscle.
- ✧ Describe the length-tension curve in cardiac muscle

Cardiovascular system

- ✧ Consists of:
  - ✓ Heart ➔ as a central pump
  - ✓ Blood vessels
- ✧ Functions:
  - ✓ Delivery of O_2 and nutrients.
  - ✓ Removal of CO_2 and wastes.
  - ✓ Transport metabolites, hormones..etc
  - ✓ Defense
  - ✓ Thermoregulation.



How the heart performs its function?

By:

- ✓ Autorhythmicity
- ✓ Conductivity
- ✓ Excitability
- ✓ Contractility

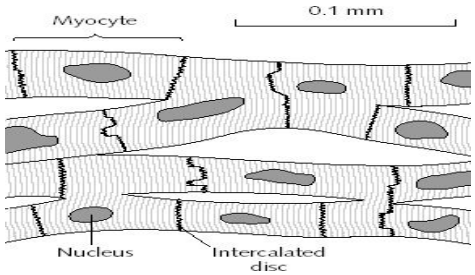
Requirement for effective pumping

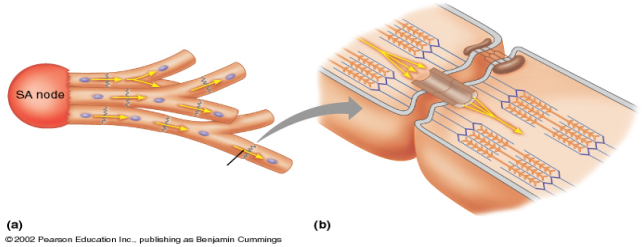
1. The contractions ccur at regular intervals.
2. The valves must open fully (not stenotic)
3. The valves must not leak (not insufficient or regurgitant).
4. The ventricular contractions must be forceful (not failing).
5. The ventricles must fill adequately during diastole.

Physiologic Anatomy of Cardiac muscle fibers

They are:

- ✓ Branched.
- ✓ Cylindrical
- ✓ Central nucleated





✧ Cardiac muscle fibers are linked together by intercalated disc

- ✓ **Enable synchronization of contraction and providing mechanical & electrical coupling**

Intercalated Disc

Desmosomes:
Anchoring intermediate filaments cytoskeleton
*prevent detachment

Fascia adherence:
anchoring actin filaments.

Gap junction:
Allows ions pass

Physiology of the Cardiac Muscle:

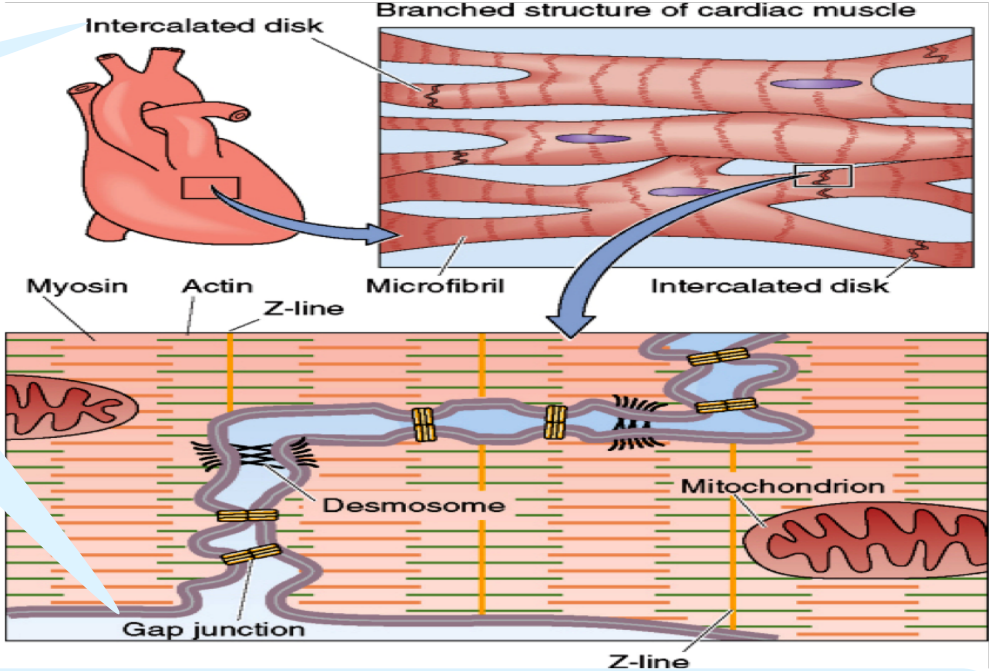
✧ Intercalated discs:

Cell membrane, separate cardiac muscle cells

✧ Gap Junctions:

Trans-membrane channel proteins, connecting the cytoplasm of the cells

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



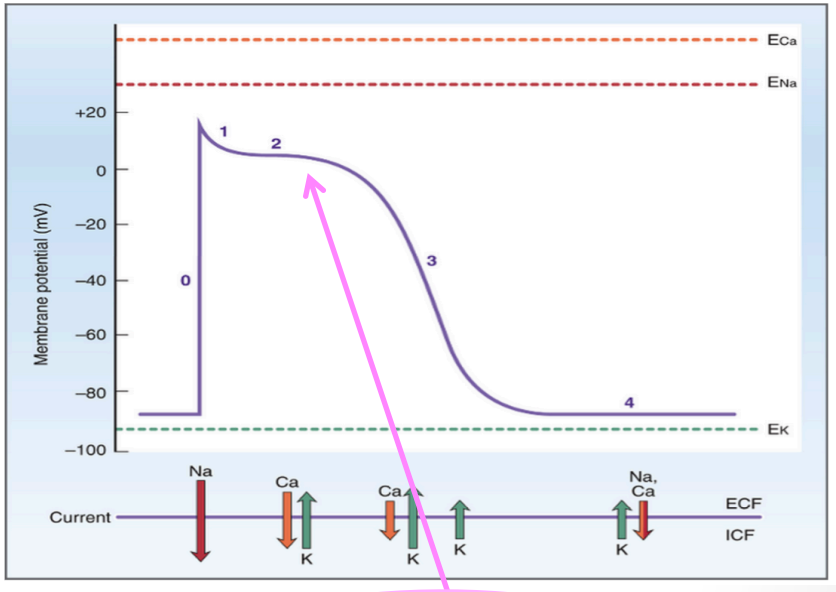
✧ Cardiac Muscle is a Syncytium:

Stimulation of a single muscle fiber ➔ The action potential spreads from cell to cell through the gap junctions ➔ contraction of all the muscle fibers.

Action Potential in Cardiac Muscle

Resting membrane potential -85 to -95mV

Phases of cardiac Action Potential	Ionic Changes
Rapid Depolarization (+20 mV) (When it reach +20 Na channel will close)	**Na^+ in**
Partial Repolarization (5-10mV) (From +20 till 0 K^+ keep going out)	**K^+ out**
Action potential plateau (0 mV) (In this steady state Ca++ moving in slowly and there is K+ going out BUT because movement is slow while 1Ca++ in slowly 2K+ out)	**Ca^{2+} in (slow)**
Repolarization (back to RMP) (No stimulation, nor impulse because there is no ion moving)	**K^+ out**



What causes the Plateau in the Action Potential?

*The slow sodium-calcium channels:
slow to open & remain open
Large quantity of both calcium and sodium ions flows to the interior of the cardiac muscle fiber, Maintains prolonged period of depolarization

Refractory Period of Cardiac Muscle

- Further stimulation of cardiac muscle depending on time 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

Absolute Refractory Period

Cardiac muscle CANNOT be re-excited while it is contracting

- ✓ To maintain pump blood and supply O2 and nutrient
- ✓ Long ARP

=Absolute Refractory period

During: **Depolarization and 2/3 Repolarization**

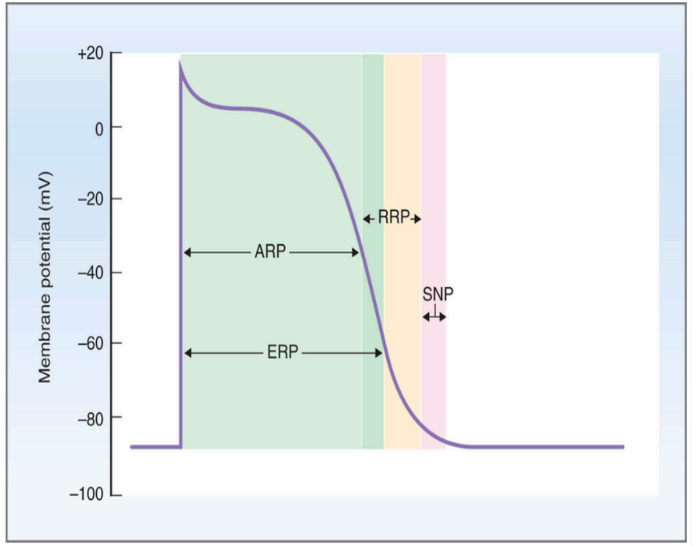
***Duration: 0.25- 0.3 sec**

Relative Refractory Period

***Cardiac muscle can be excited by STRONG STIMULUS**

During: **Repolarization**

***Duration: 0.05 sec**



*No need to memorize numbers ONLY know ARP is longer than RRP

Excitation-Contraction Coupling

Is the mechanism by which the action potential causes muscle contraction

Action Potential spreads along the T-tubules

↓

Release of calcium ions from sarcoplasmic reticulum and T-tubules[1]

↓

Calcium ions diffuse into the myofibrils

↓

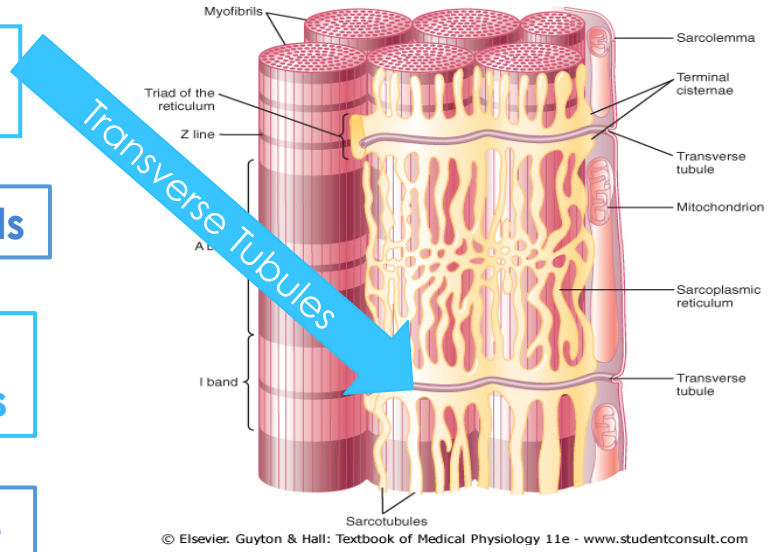
Ca^{2+} binds to troponin causing sliding of actin and myosin filaments

↓

Contraction of cardiac muscle

↓

Calcium ions are pumped back into the sarcoplasmic reticulum and the t-tubules

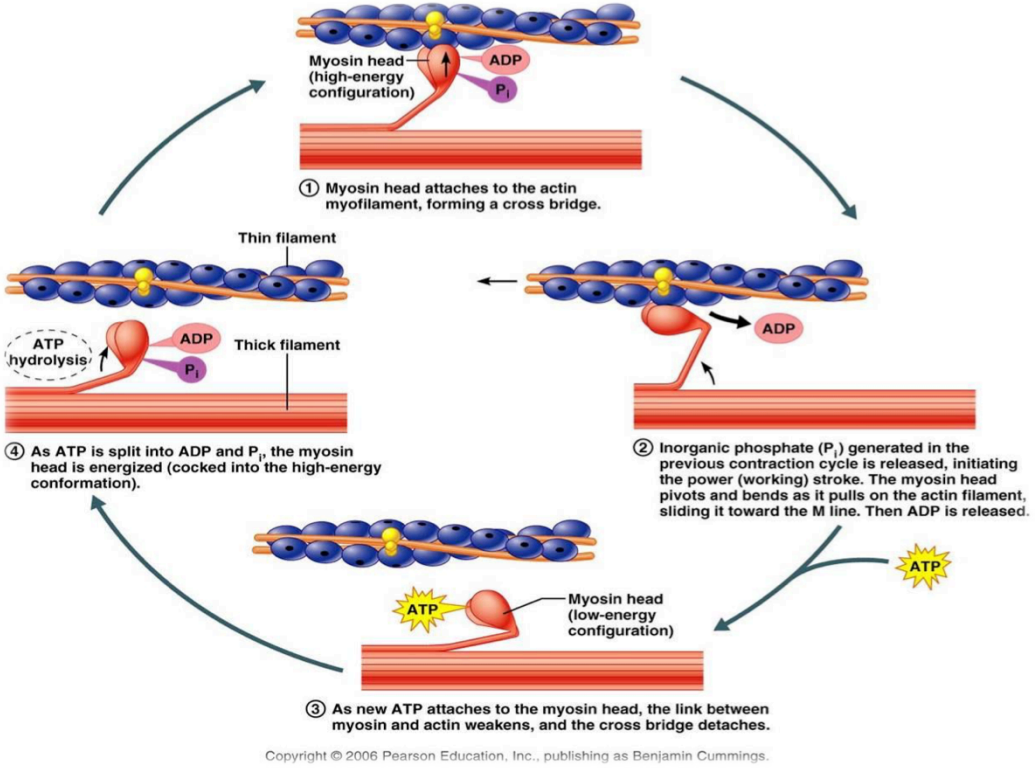


End of the Plateau
➔ Contraction ends (repolarization)

1: T tubules in the cardiac muscle stores an abundant amount of Ca ions, making them available to diffuse into the cardiac fiber when an AP appears, Without this Ca from the T tubules, The strength of cardiac muscle would be reduced. –Read more in Guyton P.104-

Excitation-Contraction Coupling cont.

- The myocytes contain large numbers of mitochondria which generate ATP by oxidative phosphorylation.
- **Cardiac muscle involve hydrolysis of ATP for contracting and sliding mechanism too.**
- Continually contracting = a lot of ATP required



Quick revision !!

The story of Muscle Counteraction: I bet we all know it by heart ;-)

Ca **combines** with troponin ➔Troponin pull tropomyosin sideway ➔**Exposing** the active site on actin ➔Myosin heads with ATP on them, **attached** to actin active site ➔The head of myosin **cross bridges** bend pulling actin toward center of sarcomere (**Power stroke**) using energy of ATP ➔ Linkage between actin & myosin broken as new ATP binds to myosin cross bridge ➔ATP hydrolyzed and cross bridge go back to its original conformation. The End!

The Contractility of the Cardiac Muscle

It is the force of contraction of the heart essential for pumping..

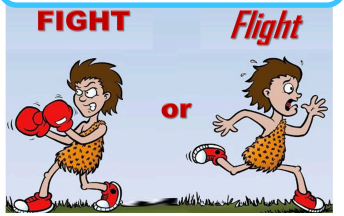
Ionotropic Effect

Mechanism (factors) that affect the contractility

Positive Ionotropic Effects

Factors that **increase** the cardiac contractility

- **Sympathetic stimulation**
  ex: Fear,exercise,stress



- **Calcium ions**

Negative Ionotropic Effects

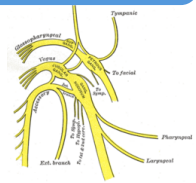
Factors that **decrease** the cardiac contractility

- **Parasympathetic stimulation**

- **Acetylcholine**

Ach

- **Vagal stimulation**



✧ Determinants of The Contractile Force of Cardiac Muscle:

- ✓ Heart rate.
- ✓ Myocardial Contractility.
- ✓ Preload: Is the load on the muscle in the relaxed state (at the end of diastole).
- ✓ Aftereload: Is the load on the muscle during contraction.(aortic pressure is the afterload on the left ventricle.

✧ Types of contractions of skeletal and cardiac muscles

- ✓ **Isometric contraction:** Force is required to stretch a resting muscle known also resting tension (passive tension).
- ✓ **Isotonic contraction:** When a muscle has contractile potential in excess of the tension required to move a load (muscle shorten & decrease length)
- ✓ **Afterloaded isotonic contraction:** Complex type of muscle contraction (typical for the heart).

MCQs

1- According to cardiac muscle, Which one of the following separates cells from one another:

A. Intercalated disc
B. Cytoplasm
C. T tubules
D. Sarcoplasmic reticulum

2- In cardiac action potential, the plateau phase occur when:

A. When sodium-calcium channels open
B. When potassium channels open
C. When sodium channels open
D. None of the above

3- Which one of the factors have a positive ionotropic effect:

A. Acetylcholine
B. Vagal stimulation
C. Sympathetic stimulation
D. Parasympathetic stimulation

1.A
2.A
3.C

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BEST OF LUCK