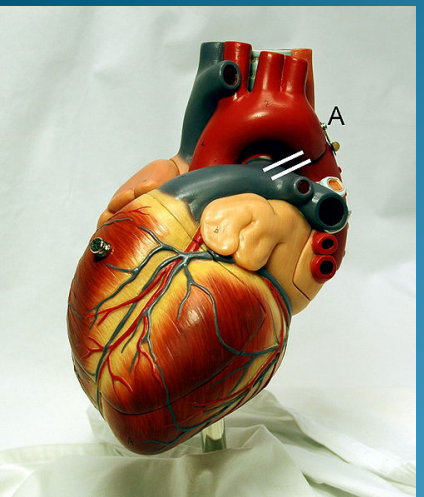
Cardiovascular System Block

Contractile Mechanism in Cardiac Muscle (Physiology)



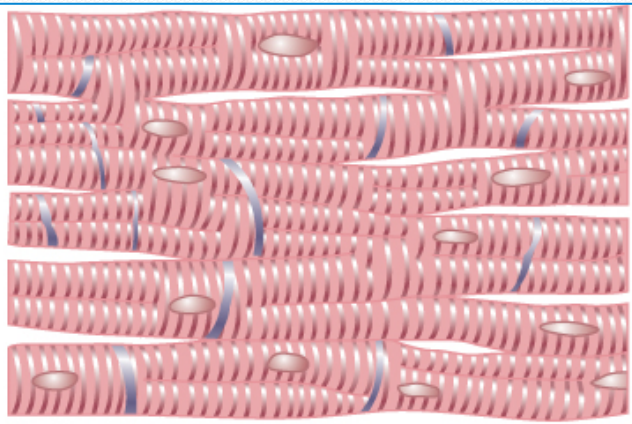
Prof. Mona Soliman, MBBS, MSc, PhD
Head, Medical Education Department
Professor of Physiology and Medical Education
Chair of Cardiovascular Block
College of Medicine
King Saud University

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

Physiology 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



Physiology of the Cardiac Muscle

- **Cardiac Muscle is a Syncytium:**
- **Stimulation of a single muscle fiber**

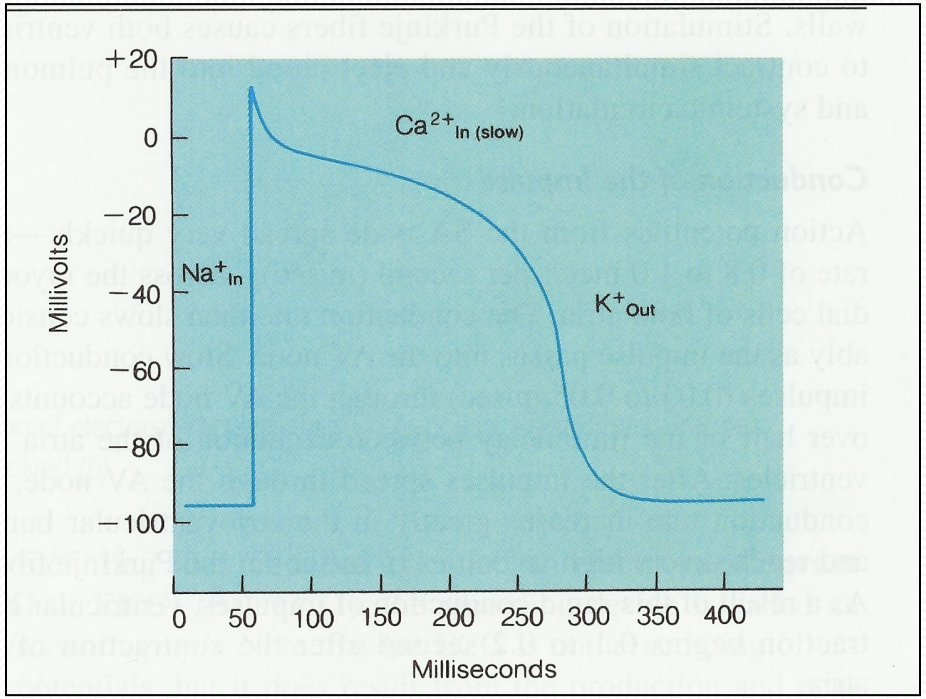
  → the action potential spreads from cell to cell through the gap junctions

  → contraction of all the muscle fibers

Action Potential in Cardiac Muscle

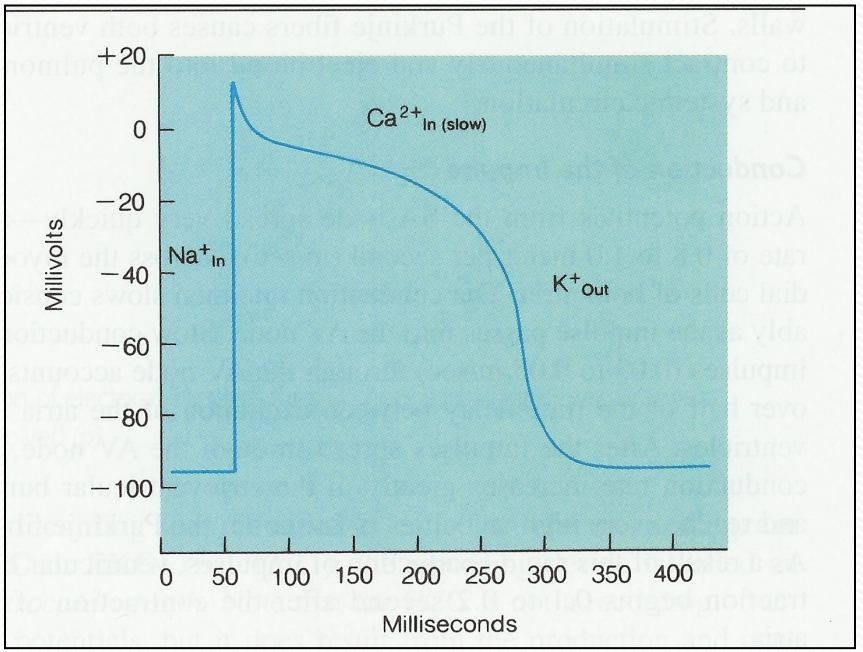
- **Resting membrane potential -90 mV**
- **Duration of cardiac action potential is 0.4 seconds**
- **Phases of Action Potential in Cardiac Muscle:**

1. **Rapid depolarization (+20 mV)**
2. **Partial repolarization (5-10 mV)**
3. **Action potential plateau (0 mV)**
4. **Repolarization (back to RMP)**



Action Potential in Cardiac Muscle

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

What causes the Plateau in the 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. *Decreased* permeability of the cardiac muscle membrane for potassium ions

   →decrease outflux of potassium ions during the action potential plateau

Action Potential in Cardiac Muscle

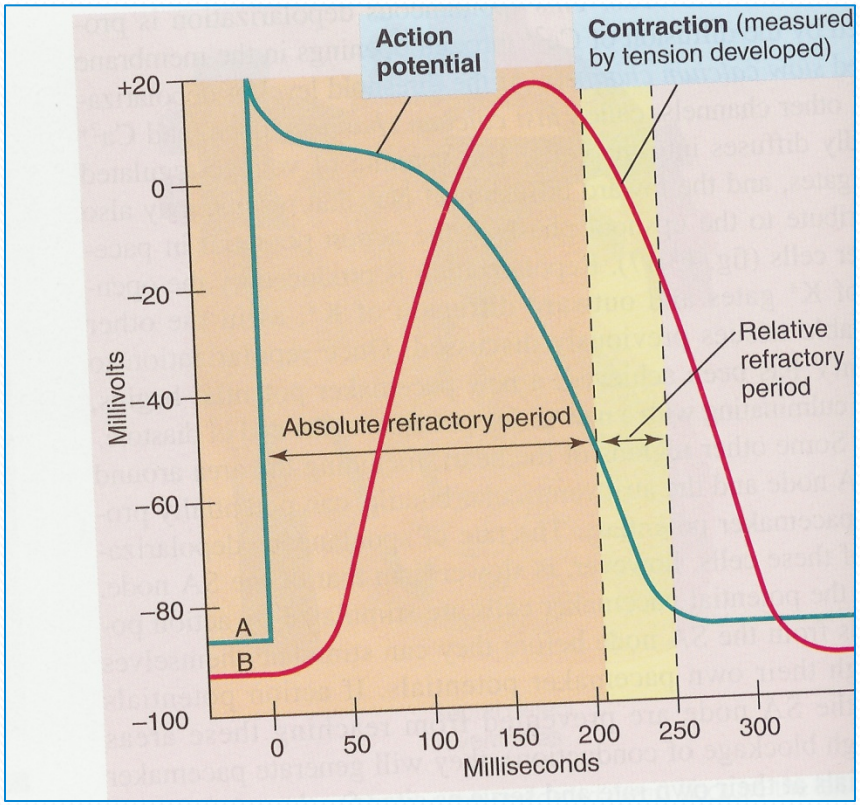
- When the slow calcium channels close at the end of the plateau,
- the membrane permeability for potassium ions increases rapidly,
- and this return the membrane potential to its resting level,
- thus ending the action potential

Refractory Period of Cardiac Muscle

- 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

Refractory Period of Cardiac Muscle

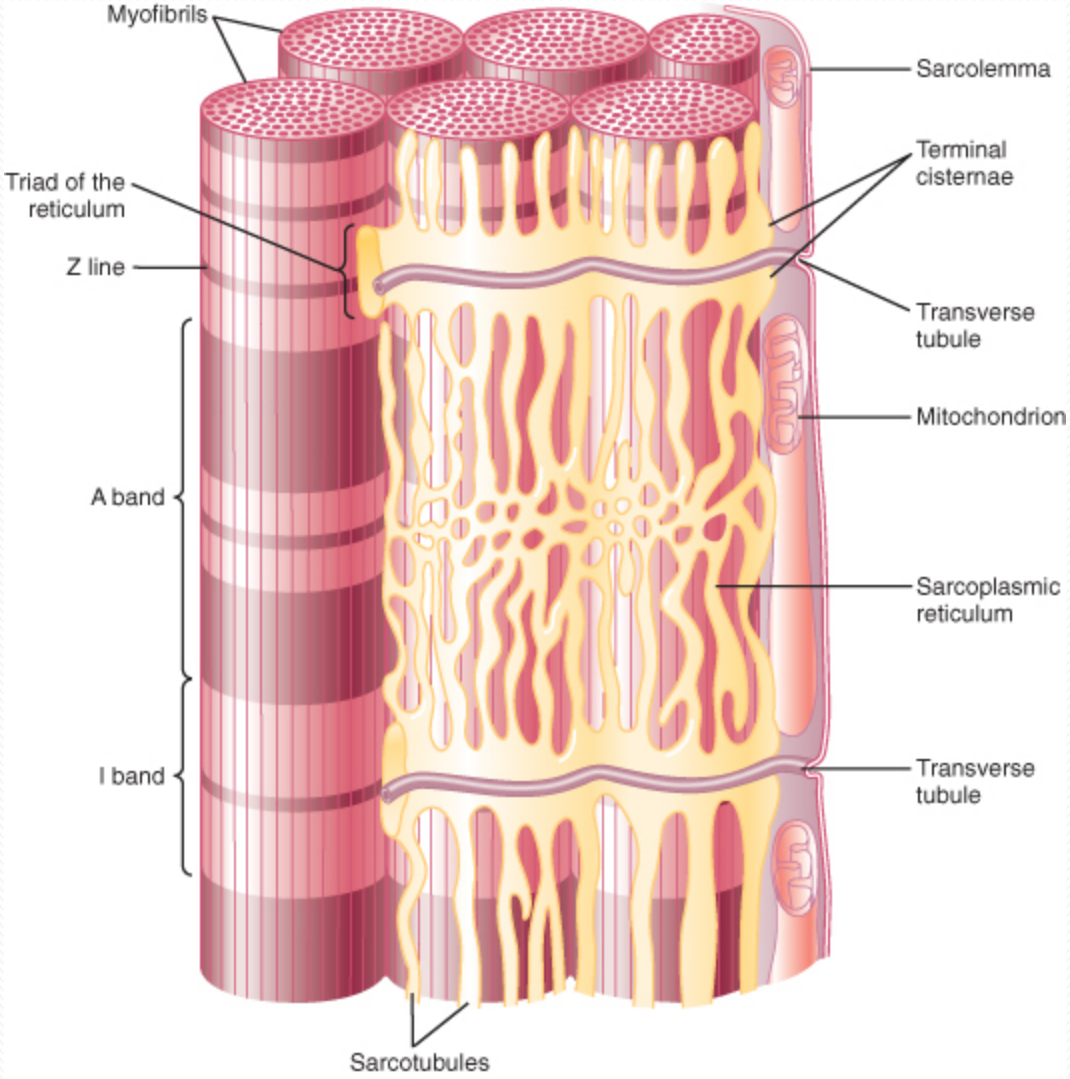
- **Absolute refractory period**
  - Cardiac muscle cannot be excited while it is contracting … benefit?
  - Long ARP
  - Time: depolarization and 2/3 repolarization
  - Duration: 0.25- 0.3 sec
- **Relative refractory period**
  - Cardiac muscle can be excited by strong stimulus
  - Time: repolarization
  - Duration: 0.05 sec



Excitation – Contraction Coupling

- **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

Transverse (T) tubule-sarcoplasmic reticulum system



Excitation – Contraction Coupling

Action Potential spreads along the T-tubules

↓

1. Release of calcium ions from sarcoplasmic reticulum into the sarcoplasm
2. Large quantity of extra calcium ions diffuses into the sarcoplasm from the T tubules

↓

Excitation – Contraction Coupling

↓

Calcium ions diffuse into the myofibrils

↓

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

↓

Contraction of cardiac muscle

Excitation – Contraction Coupling

- At the end of the Plateau of the action potential

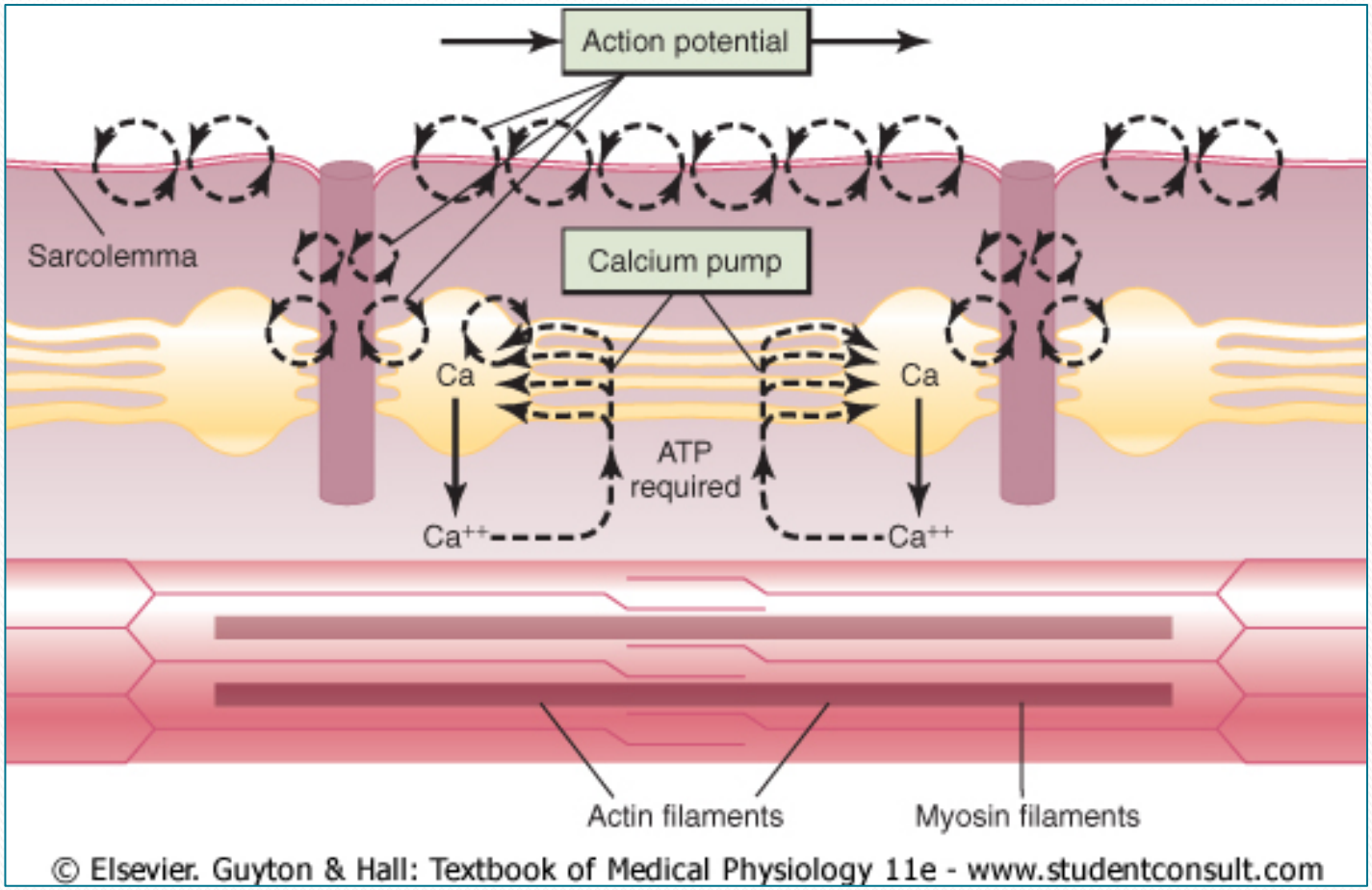
  → calcium ions are pumped back into the sarcoplasmic reticulum and the T-tubules

  → contraction ends (repolarization)

Excitation – Contraction Coupling

- 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



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

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***
  - ***Sympathetic stimulation***
  - ***Calcium ions***
- ***Negative Ionotropic Effects: factors that decrease the cardiac contractility***
  - ***Parasympathetic stimulation***
  - ***Acetylcholine***
  - ***Vagal stimulation***

For further readings and diagrams:

Textbook of Medical Physiology by Guyton & Hall

Chapter 9 (Heart Muscle)