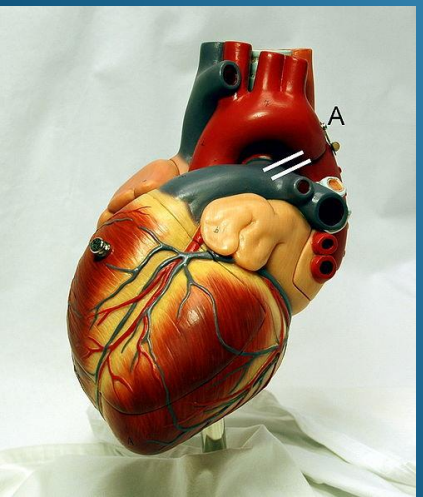
Cardiovascular System Block

Contractile Mechanism in Cardiac Muscle (Physiology)



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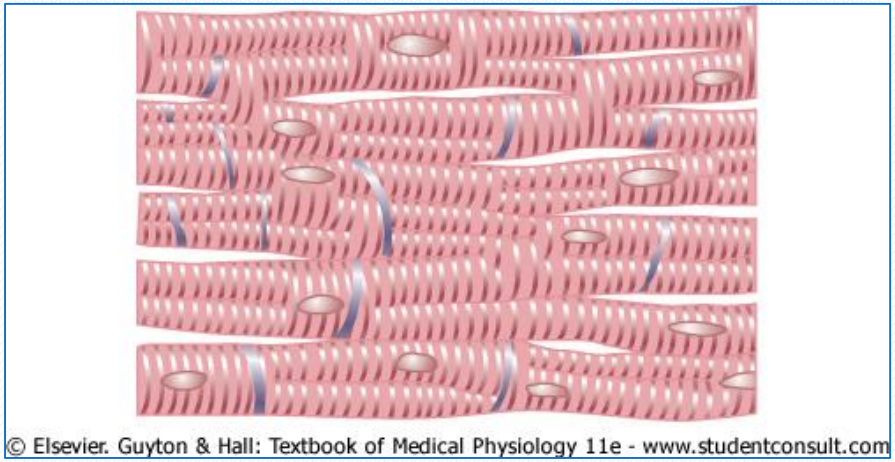
Objectives

- 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**

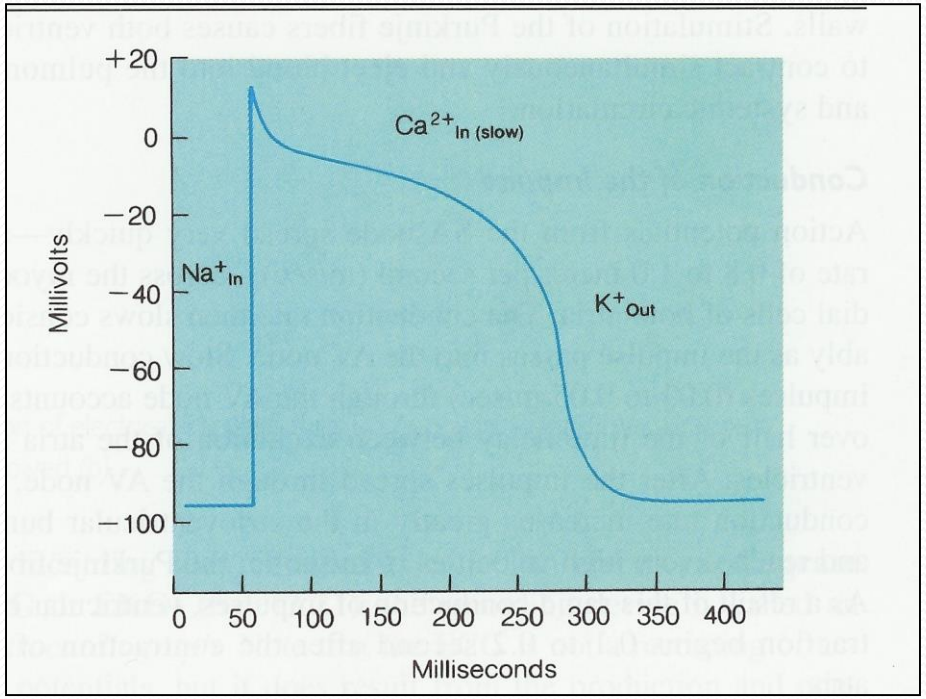
  → the action potential spreads from cell to cell through the gap junctions

  → contraction of all the muscle fibers

Action Potential in Cardiac Muscle

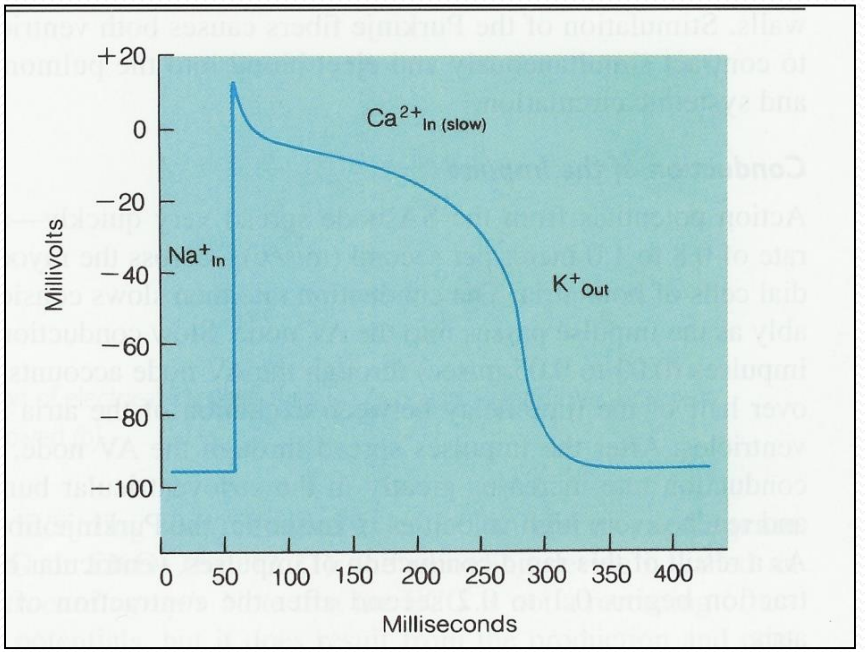
- **Resting membrane potential -90 mV**
- **Duration of cardiac action potential is 0.4 seconds**
- **Phases of Action Potential in Cardiac Muscle:**

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

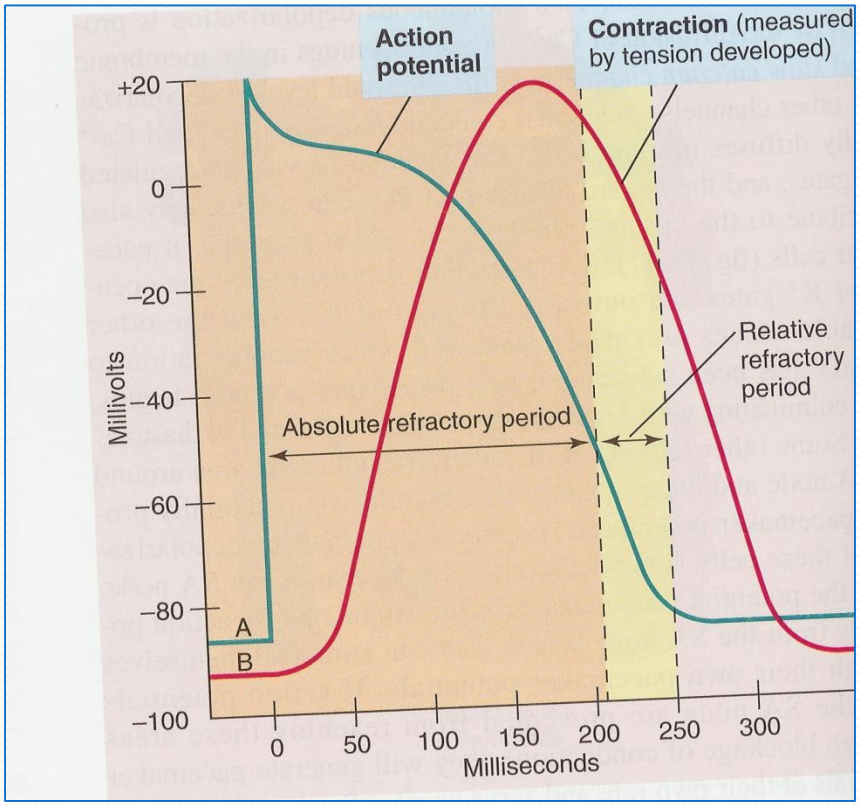
- When the slow calcium channels close at the end of the plateau,
- the membrane permeability for potassium ions increases rapidly,
- and this return the membrane potential to its resting level,
- thus ending the action potential

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

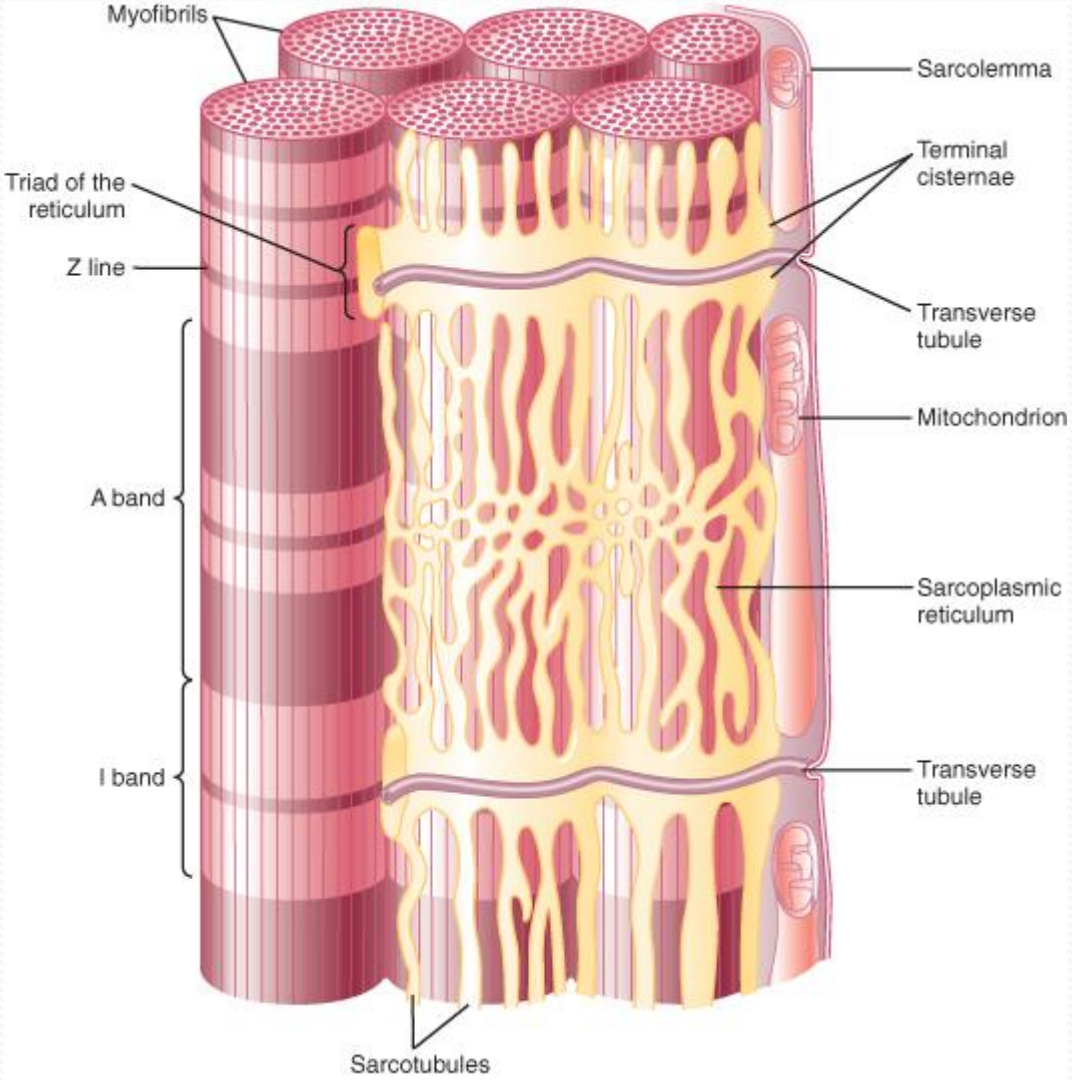
- **Absolute refractory period**
  - Cardiac muscle cannot be excited while it is contracting … benefit?
  - Long ARP
  - Time: depolarization and 2/3 repolarization
  - Duration: 0.25- 0.3 sec
- **Relative refractory period**
  - Cardiac muscle can be excited by strong stimulus
  - Time: repolarization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

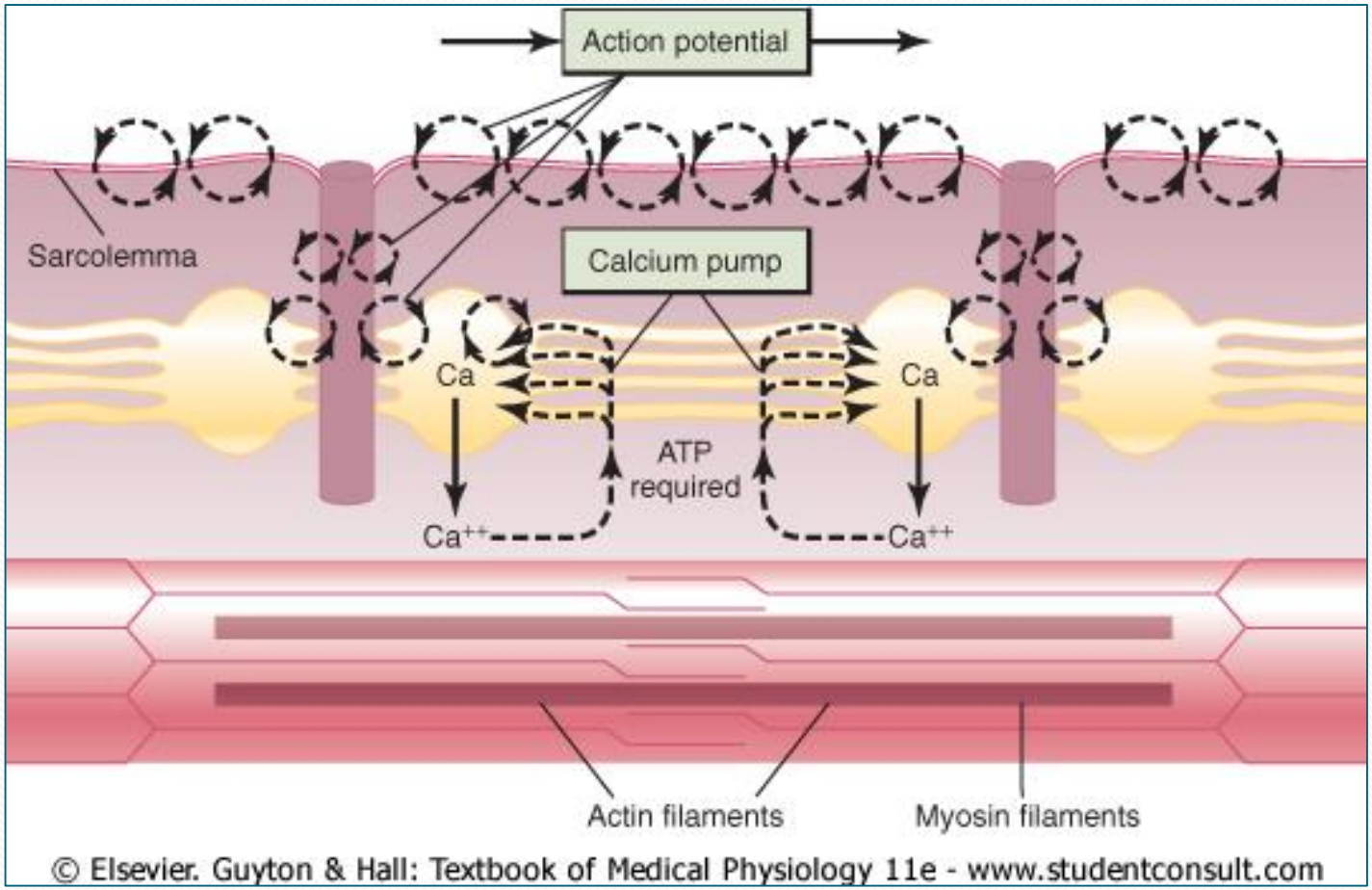
  → calcium ions are pumped back into the sarcoplasmic reticulum and the T-tubules

  → 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)