Physiology of Excitable tissue
L7
Cardiac muscles

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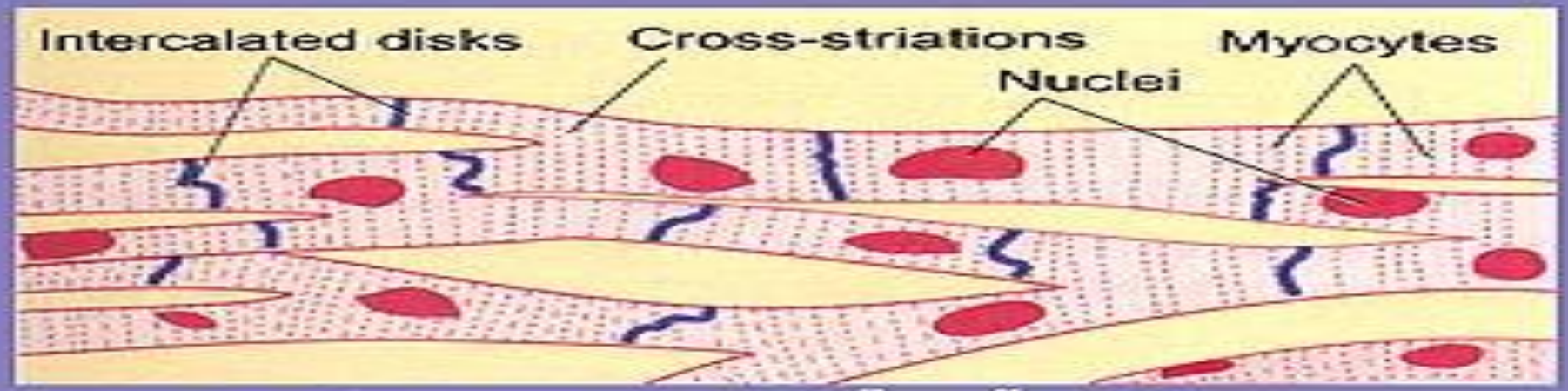
Excitable Tissues

Types of Muscles

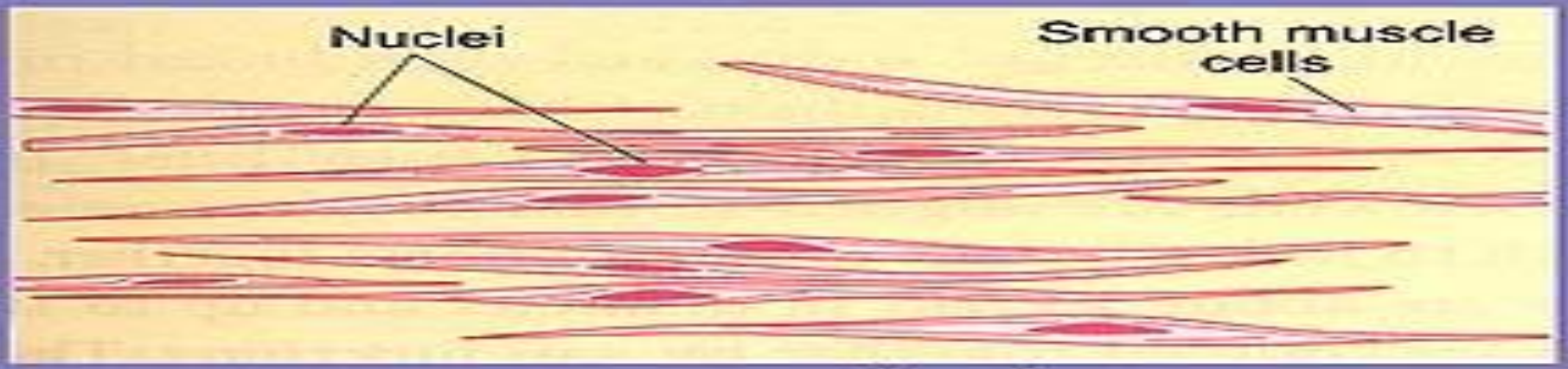
- Skeletal muscle
- Smooth muscle
- Cardiac muscle

Skeletal	Smooth	Cardiac
Striated	Non Striated	Striated
Somatic	Visceral	Cardiac
Voluntary	Involuntary	Involuntary
Nerve Operated	Nerve regulated	Nerve regulated
Supplied by Somatic m. n.	Supplied by Autonomic n.	Supplied by Autonomic n.
Neurogenic	Myogenic	Myogenic
Bulk	Sheath	Characteristic
Long m. fibers	Short	Branching
Isolated	Elect., Mech. Con.	Elect., Mech. Con.

Skeletal muscle (กล้ามเนื้อลาย)



Cardiac muscle (กล้ามเนื้อหัวใจ)

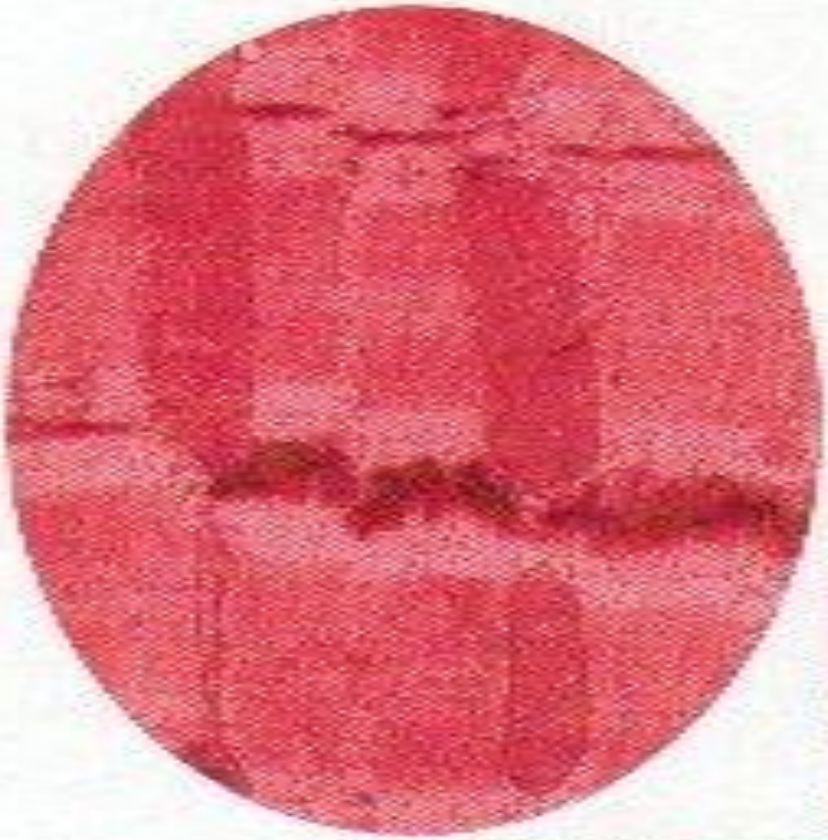


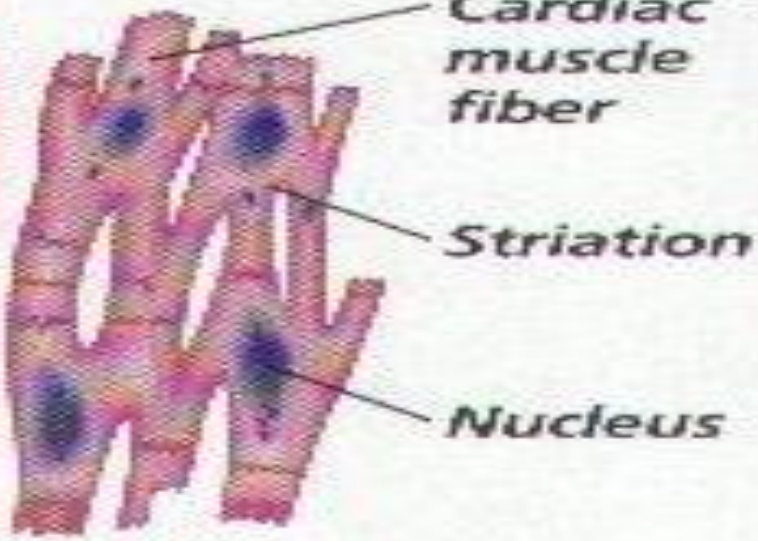
Smooth muscle (กล้ามเนื้อเรียบ)

Types of Skeletal Muscles

Red muscles	White Muscles
Red color, Rich in Blood & Myoglobin	White color, Poor in Blood & Myoglobin
Large size Like thigh m. Formed of large M.U.	Small size Like Finger m. Formed of small M.U.
Strong contraction But Slow	Weak contraction But Fast
Not easily fatigable	easily fatigable
Rough coarse movement	Fine delicate movement
Long duration of A.P & S.M.T.	Short duration of A.P & S.M.T.

Cardiac muscle

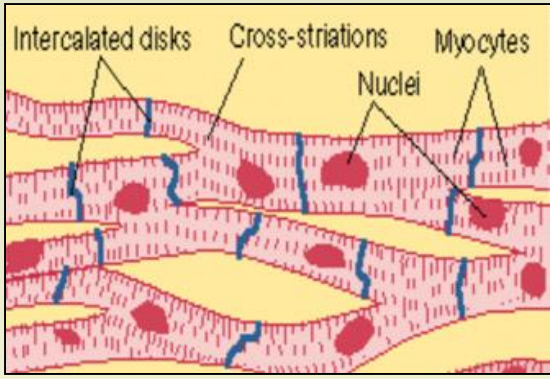




Magnification: 27 000×

Cardiac muscle fibers, which are also under involuntary control, appear striated or striped when magnified.

Properties of cardiac muscles



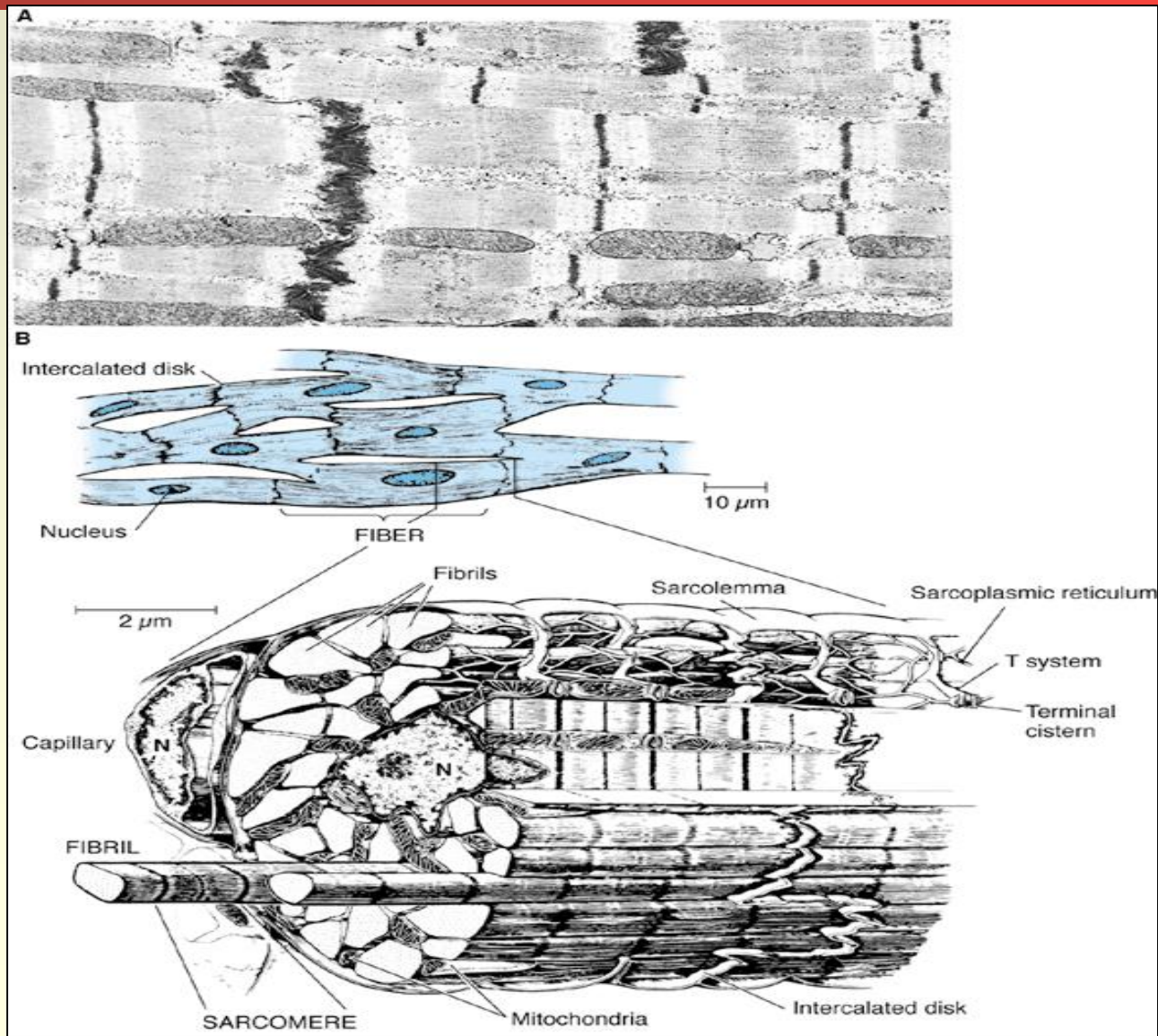
1. Striated like in skeletal muscle.
2. Branching & interdigitating.
3. Each single cell has a complete separated muscle membrane.

3. The cardiac muscle are involuntary like smooth muscle (myogenic property) & nerve regulated.

4. They receive parasympathetic through the vagus but the sympathetic is mainly through adrenaline & nor-adrenaline that is present in blood.

Cardiac Muscle; Morphology

- **Striated.**
- **Branching Intercalated disks**



Properties of cardiac muscles

5. They have intercalated disc, which represents the attachment between one cardiac muscle fiber & its adjacent one

Electrical & mechanical interconnection

Intercalated disc are formed from series of folds situated near the Z-line of the actin & myosin.

So that it is important for electrical connection and it is also provide mechanical cell to cell connection.

If we do stimulation of one muscle fiber, the effect will spread to all cardiac muscle

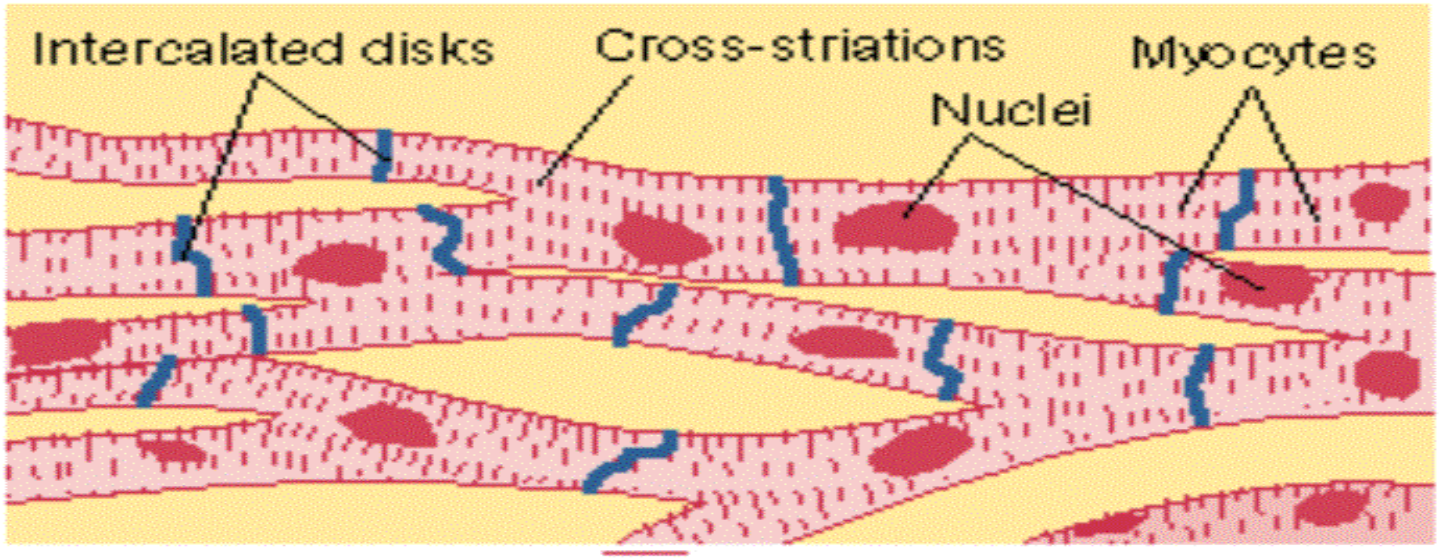
Act as single syncytium (single unit).

Follow all or None law

All or None law

1. Cardiac muscles.
2. Unitary smooth muscles.
3. Single nerve fiber.
4. Single skeletal muscle fiber.

Intercalated discs



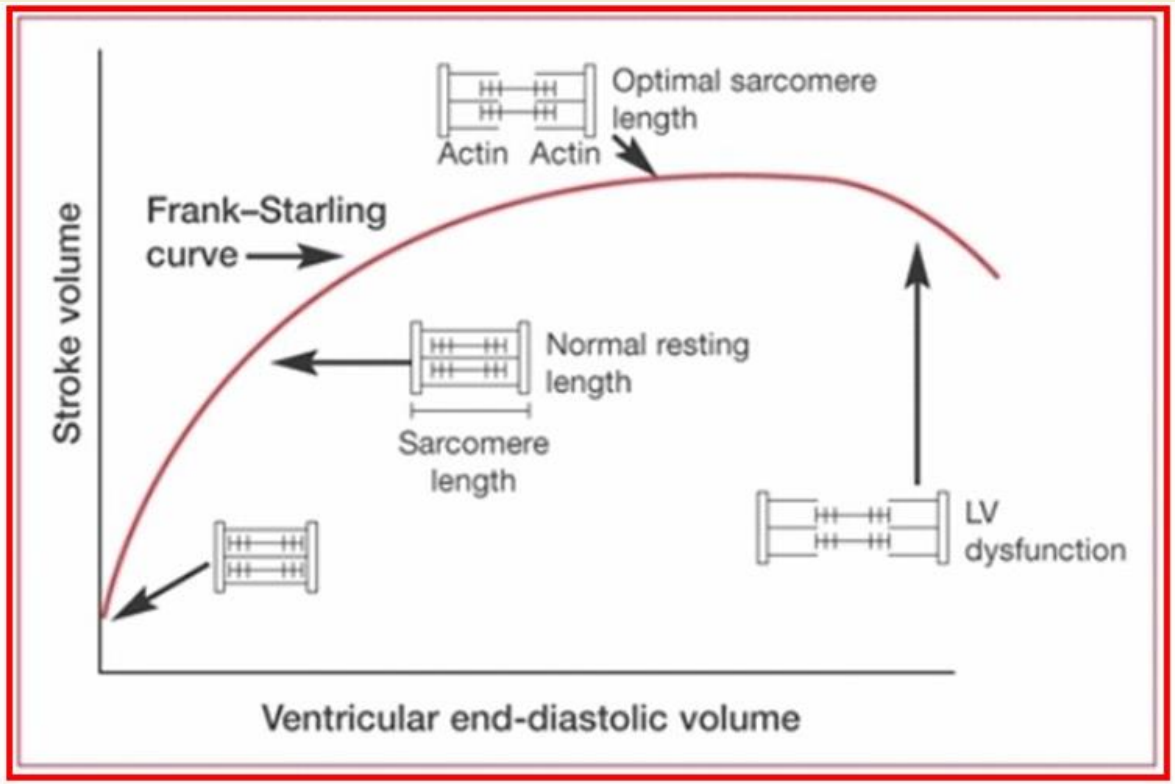
<u>Another property is that the:</u>

6. T-Tubules are situated at the Z- line rather than the A-I Junction like the skeletal muscles

Cardiac muscle tone and Starling law

Starling law:

Stretching of the muscle ➡⬆ force of its contraction till certain limit after which stretching will produce ⬇ in the force of contraction.



Cardiac muscle tone & Starling law

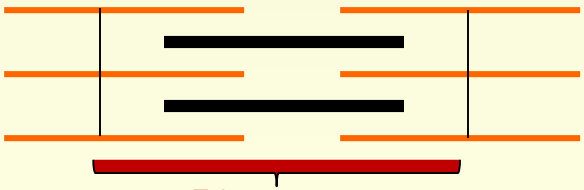
Why starling law is more effective in cardiac muscles:-

- **Skeletal muscle are fixed with bone attachment**

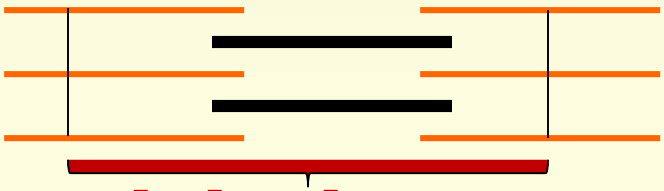
  (So their stretching is limited)

- **The resting length of the cardiac sarcomer is less than that of skeletal muscles**

  (So they are more liable for stretching)



Cardiac 1.8 µm



Skeletal 2.2 µm

Actin = 1 µm **myosin = 1.5 µm.**

Other properties

7. Electrical property of cardiac muscle:

a. The R.M.P. is stable (– 80 mV).

Also m. contraction should be preceded by by A.P.

b. The A.P. of the cardiac muscle

- Prolonged duration (150 - 250 msec.)
- Plateau due to opening of slow Ca^{+2} channels.
- Overcomes nearly almost all the contraction & relaxation phases.

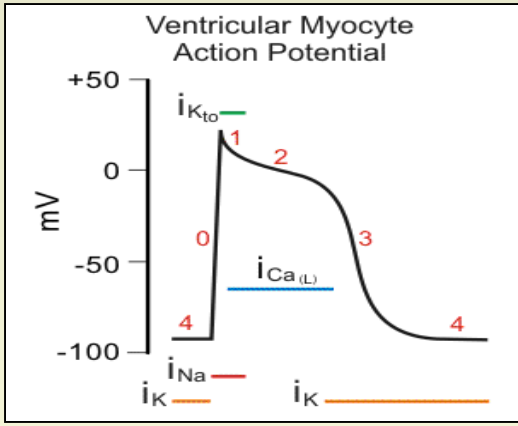
This phenomena protect the cardiac muscle from tetanic contraction which if occurs it is fatal.

The absolute refractory period include all the contraction & most of relaxation time.

Cardiac action potential

1) The A.P. of the cardiac muscle is of 4 phases:

0. Depolarization, Influx of Na+.
1. Early repolarization, Efflux of K+.
2. Plateau (opening of Ca^{+2} channels).
3. Repolarization Efflux of K+.



2) Duration of A.P. is about 0.15-0.25 msec

3) The duration is variable depending on the heart rate,

H. rate is ≈ 75 beat/min so the duration is 0.25 sec.

H. rate is ≈200 beat/min so the duration is 0.15 sec.

This shortening occurs mainly by prolongation of the relaxation phase.

Cardiac Muscle Electrical Properties

RMP & Action Potentials

RMP = about -90 mV.

A.P. = On stimulation propagated A.P. ⟹ contraction

A.P.

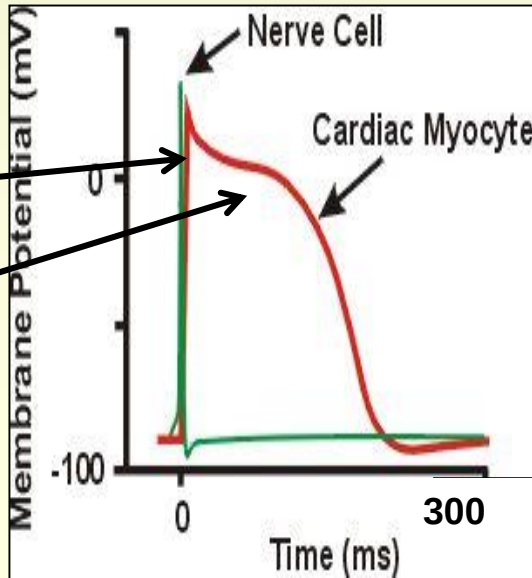
Depolarization ⟹ Overshoot (as in skele. M. & n.)

but this is a plateau before repolarization

Depolarization = 2 ms.

Plateau phase & repolarization = 200 ms.

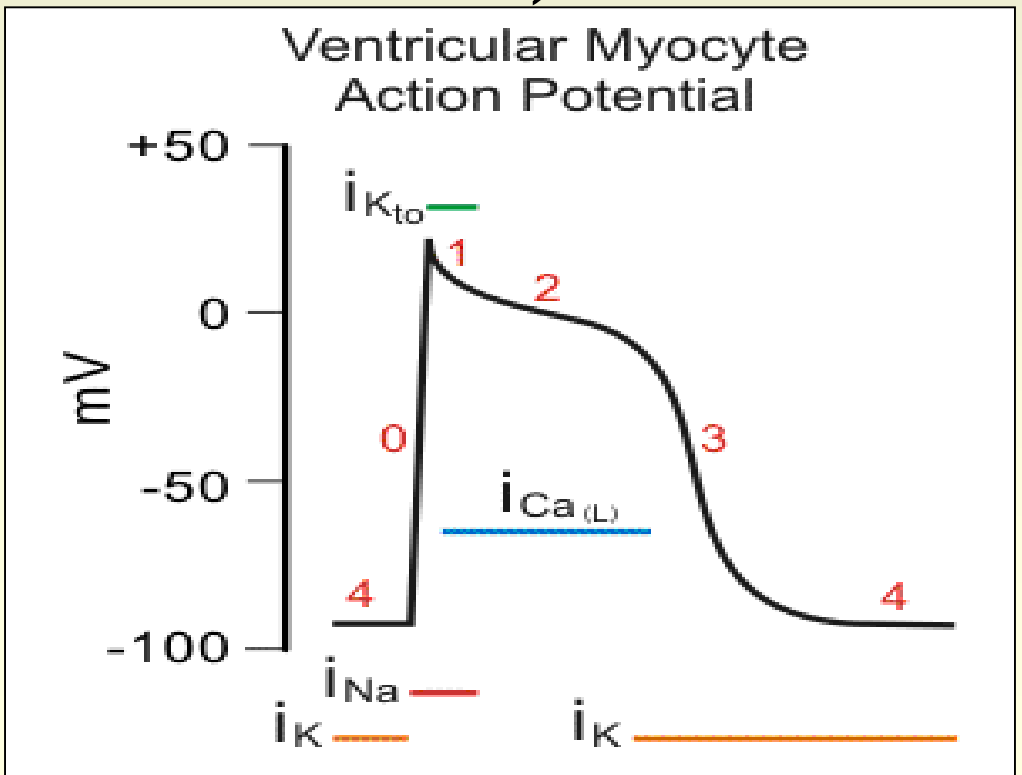
So the A.P. covers the whole SMT.



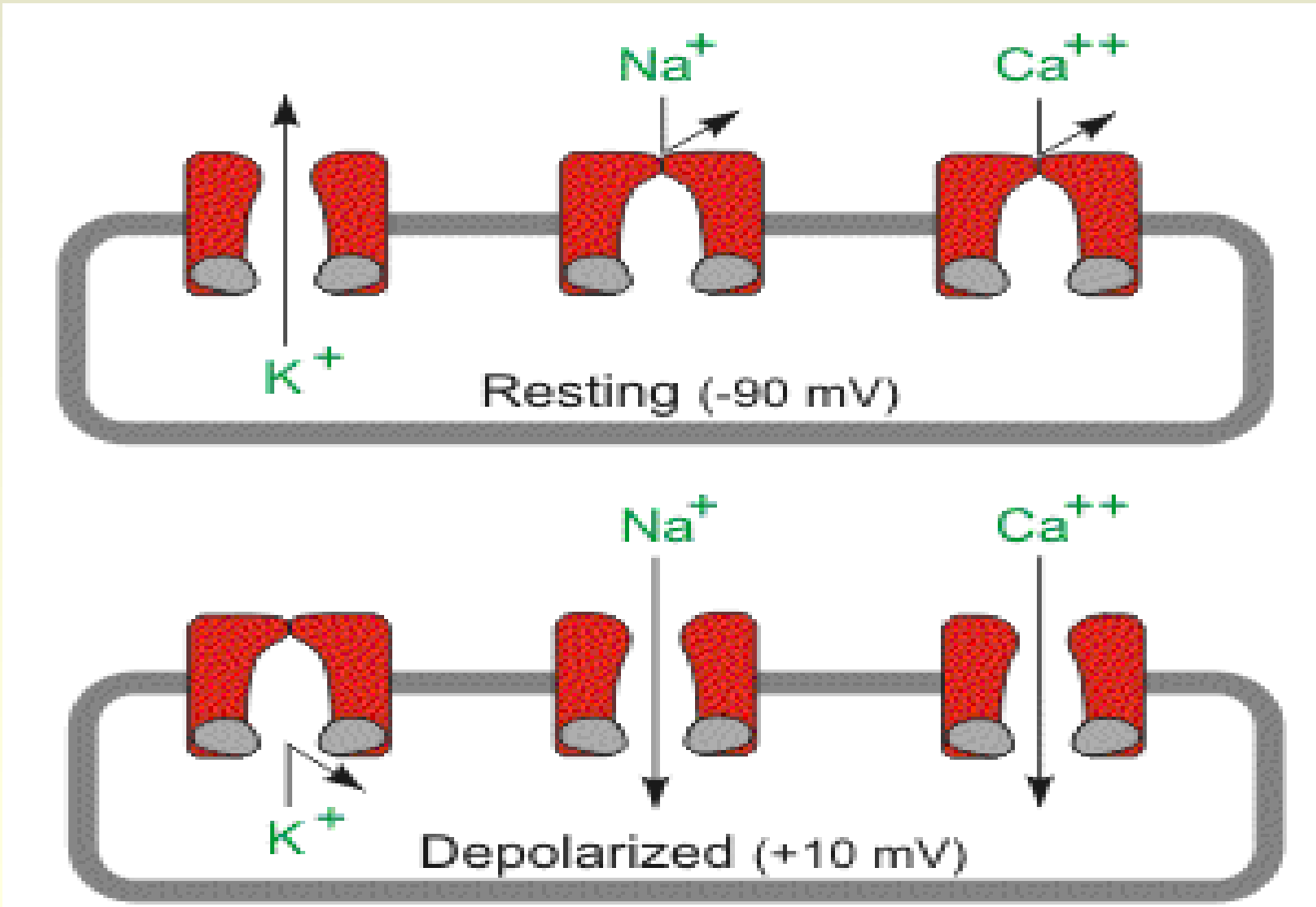
Cardiac action potential

Phases of cardiac action potential:

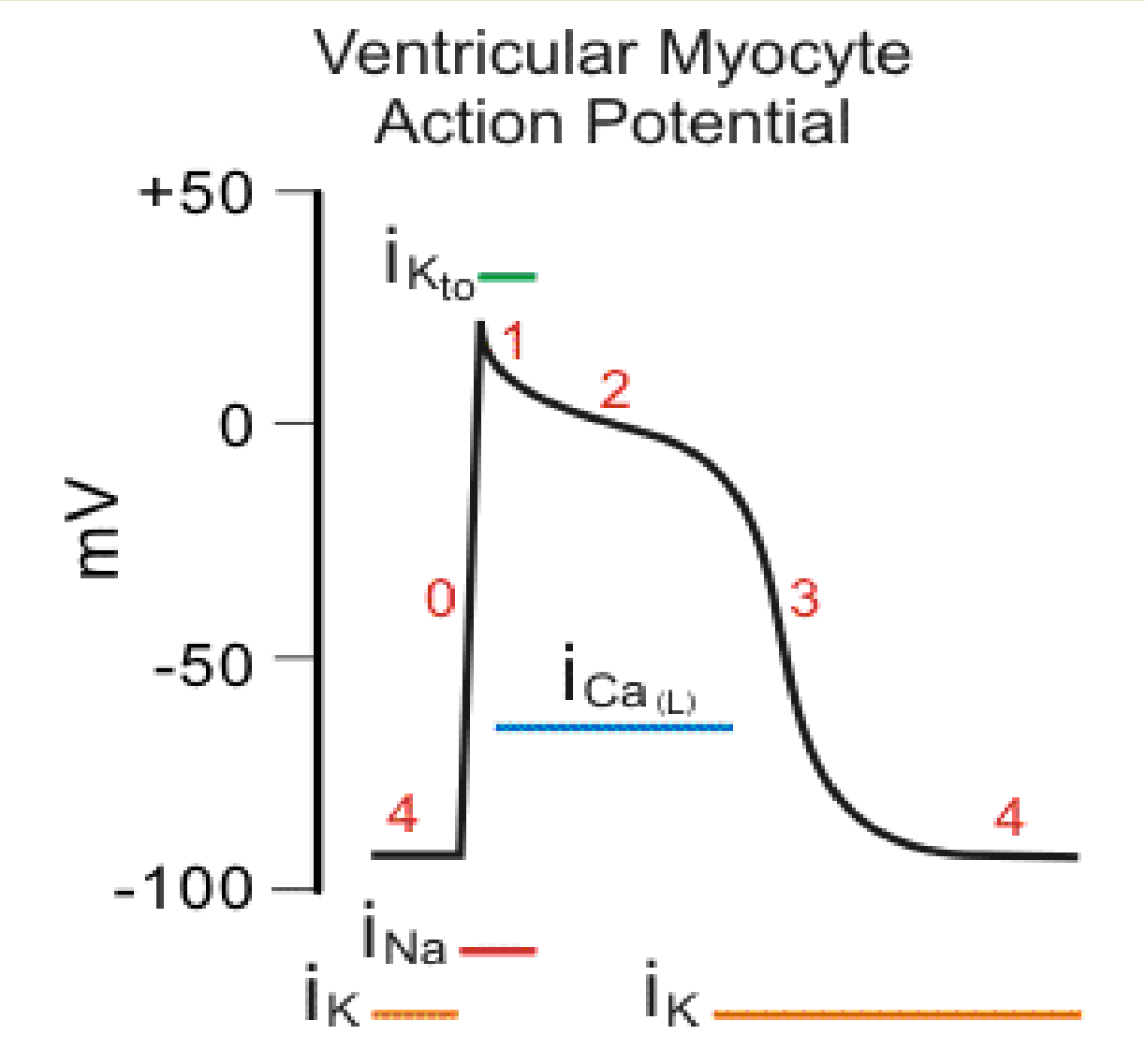
0. **Influx of Na+.**
1. **Efflux of K+.**
2. **Plateau (opening of Ca^{+2} channels).**
3. **Repolarization.**
4. **RMP**



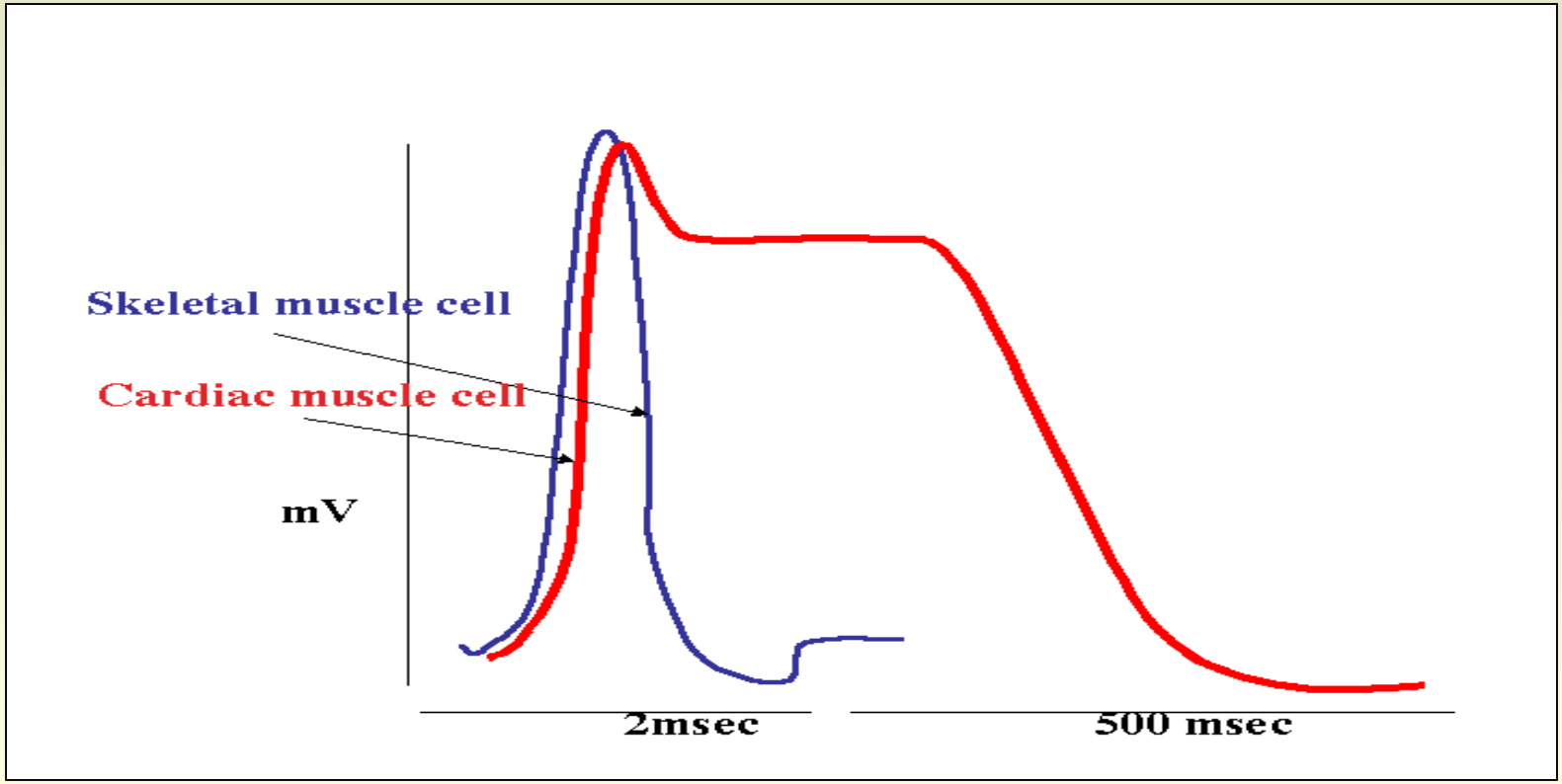
Calcium channels



Cardiac Muscle proper action potential



Comparison between cardiac & skeletal muscle action potential



Duration of Cardiac A.P. is much longer 150-250 msec.

Duration of smooth muscle A.P. 50 msec.

Duration of skeletal muscle is about 2-4 sec.

Type of Cardiac muscles

1. Cardiac muscle proper.
2. Pacemaker cells.
   - S.A. Node.
   - A.V. Node.
3. Conductive cells.
   - Perkenji fibers.

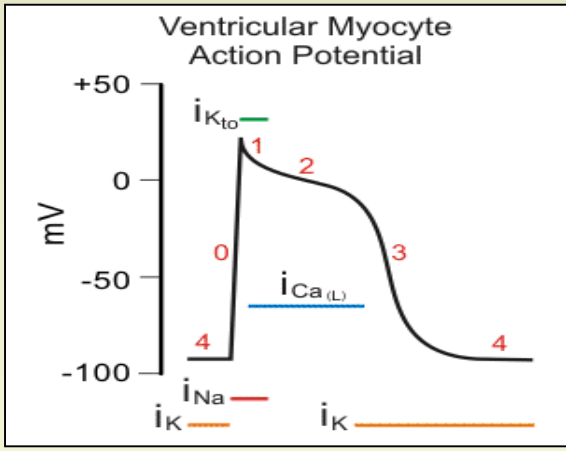
Types of cardiac muscles

1. Cardiac muscle proper:

Responsible for contraction

Their AP is of wide duration

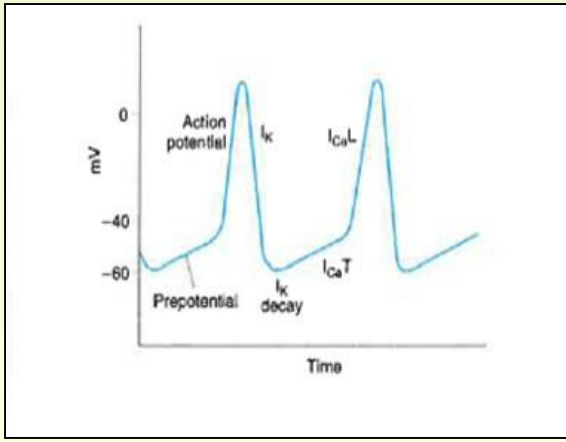
(250-300 msec.)



2. Pacemaker cells: SA, AV node

Modified cardiac cell initiate AP

Their AP related to Ca^{+2}



3. Conductive cells (Perkenji fibers).

Pacemaker cells

Pacemaker cells:

These cells are specialized to initiate A.P. (spontaneous).

They have different electrical properties.

They have unstable R.M.P.

Pacemaker A.P.:

The permeability of membrane against k^{+} is variable.

There is a gradual shifting of R.M.P. toward the firing level as there is accumulation of K ions inside the cells.

There is opening of Ca^{+2} channels.

This continue till there is shift of the R.M.P to the firing level and A.P. will occur.

Cardiac muscle force of contraction

The force of cardiac muscle contraction can be changed

Catecholamine produce (+ve) inotropic effect

(+ve) inotropic effect

With the same degree of stretching

the cardiac muscle produces more contraction

Because ↑ Catecholamine

↑ C-AMP Synthesis → Prolong open Ca channels

so ↑ Ca^{++} to the contraction elements.

Cardiac muscle force of contraction

In (+ve) inotropic effect

The ↑ in the force of contraction occurs without much increase in the oxygen supply

There is increase in the performance of cardiac muscle