Myocardial cell physiology

Sotiris Papaspyros

June 2006

Content

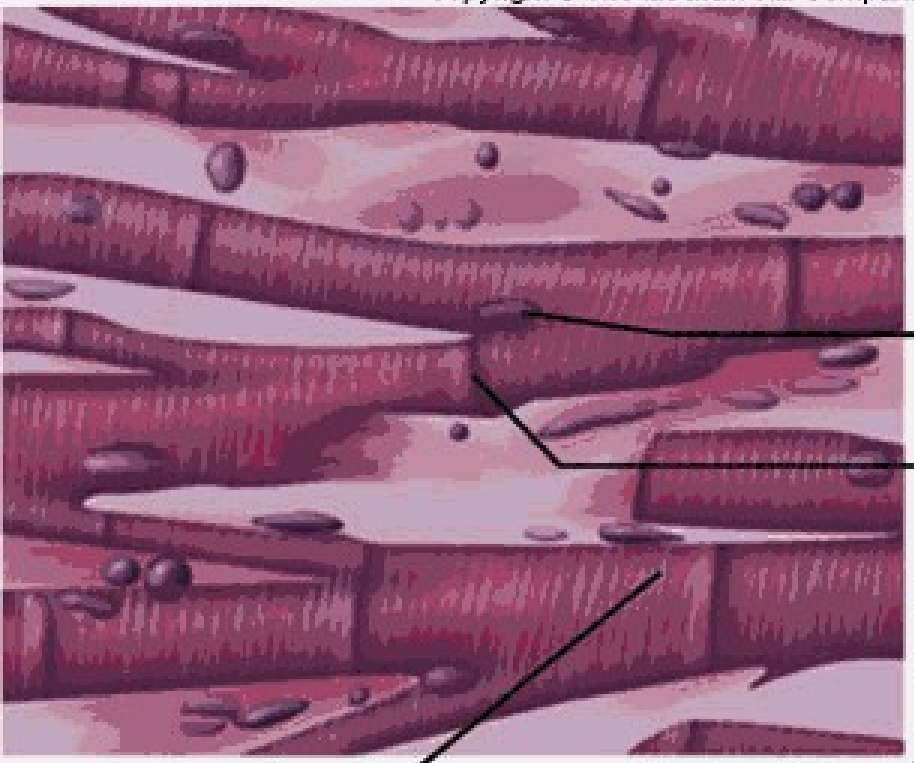
- Physiologic anatomy.
- Action potentials.
- Excitation-Contraction coupling.
- Conductive pathways.

Three types of cardiac muscle

1. Atrial.
2. Ventricular.
3. Excitatory and conductive muscle fibers.

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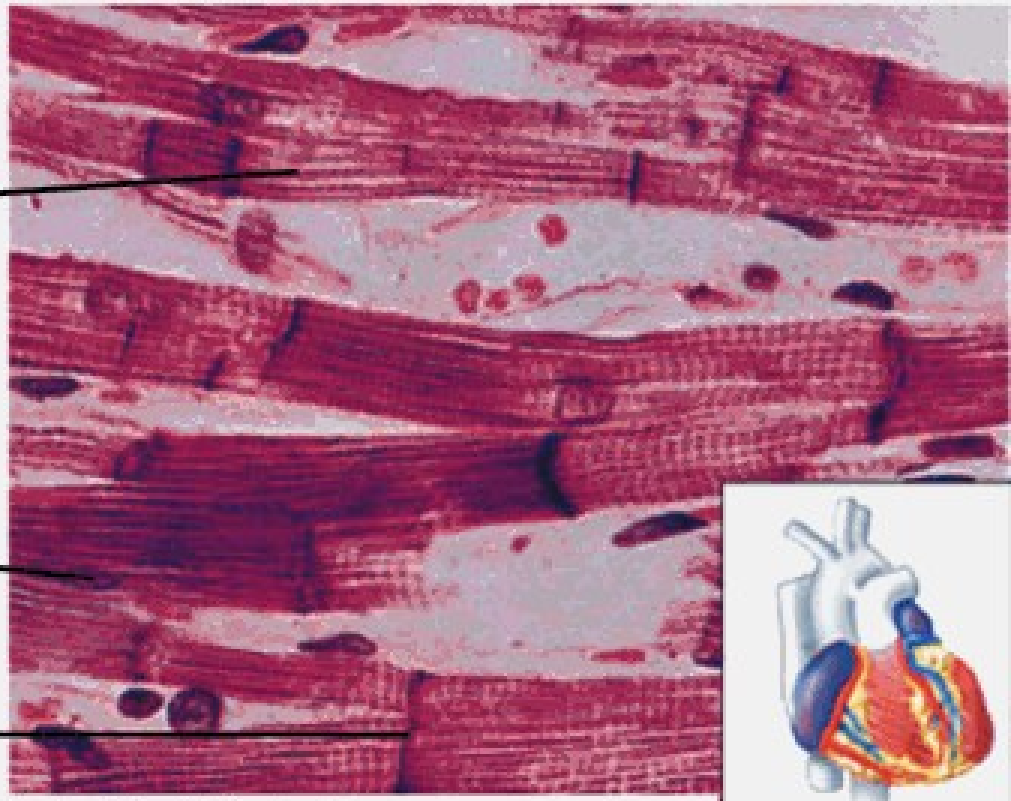
Cardiac Muscle Tissue



Nucleus

Intercalated disk

Striations



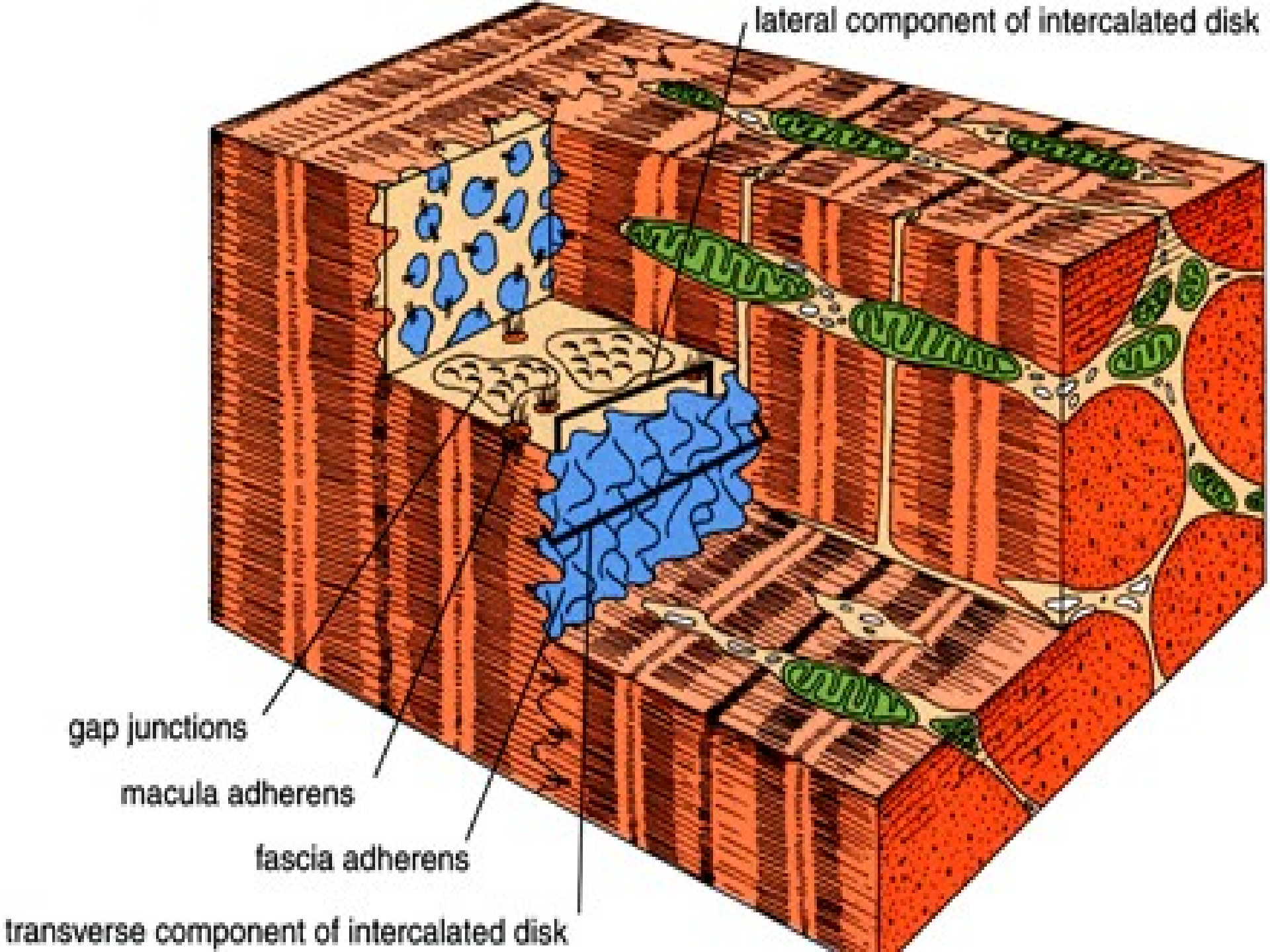
Nucleus

Intercalated disk

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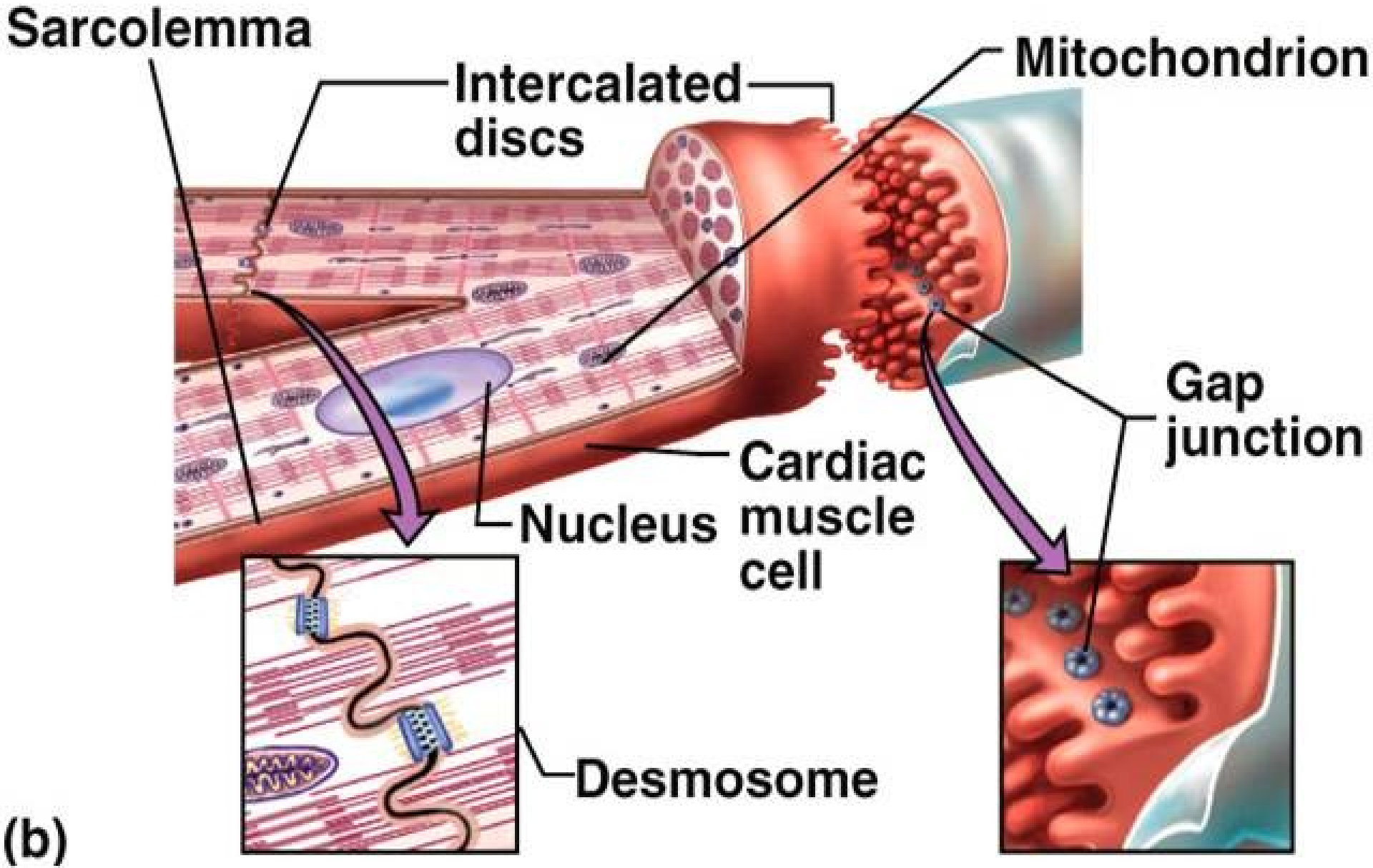
Characteristics-Cardiac muscle as a Syncytium

- Striated.
- Typical myofibrils that contain actin-myosin filaments.
- Intercalated discs (gap junctions).


lateral component of intercalated disk
gap junctions
macula adherens
fascia adherens
transverse component of intercalated disk

Intercalated discs

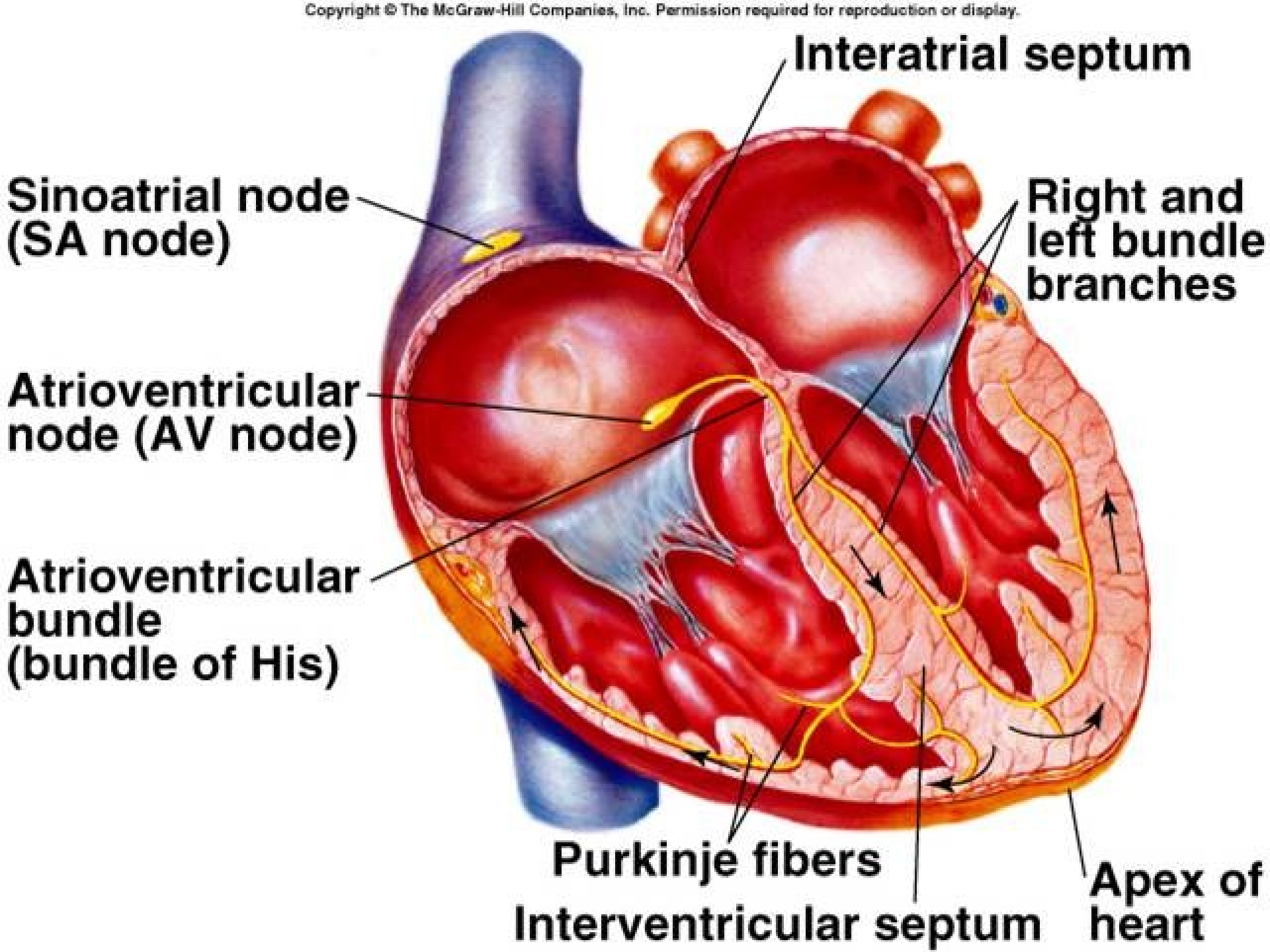
- Cell membranes separating cardiac muscle cells from one another.
- Electrical resistance through the discs is 1/400 of the resistance through the outside membrane because of:
- The cell membranes fuse with each other forming gap junctions (allow totally free diffusion of ions).


Sarcolemma
Intercalated discs
Mitochondrion
Gap junction
Cardiac muscle cell
Nucleus
Desmosome
(b)

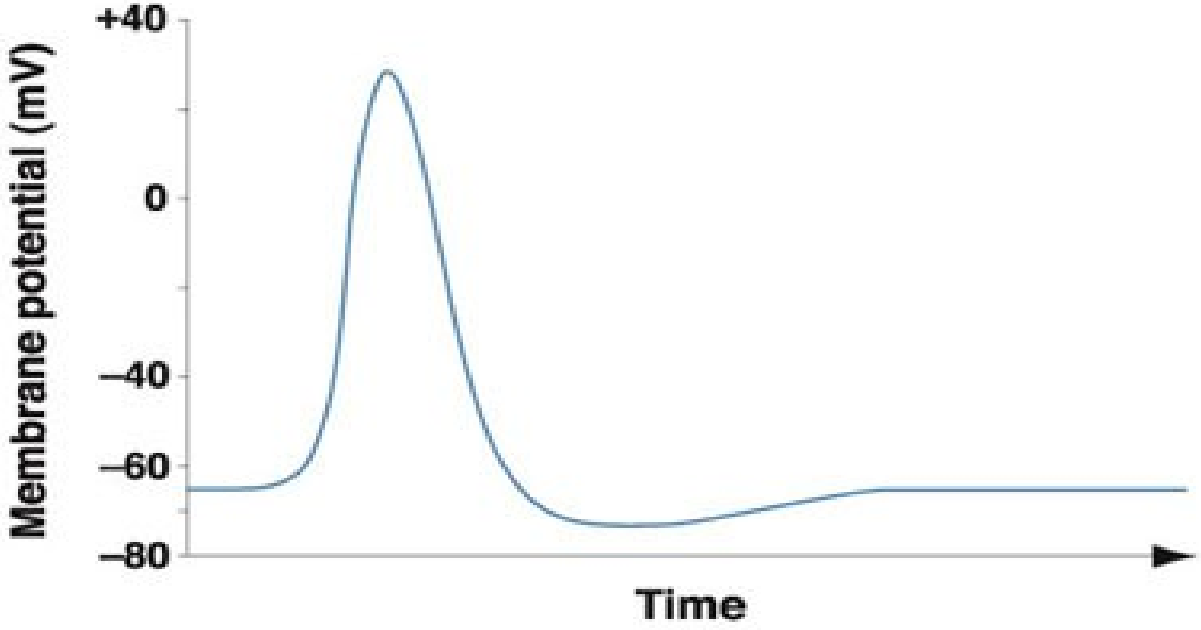
Two functional syncytiums

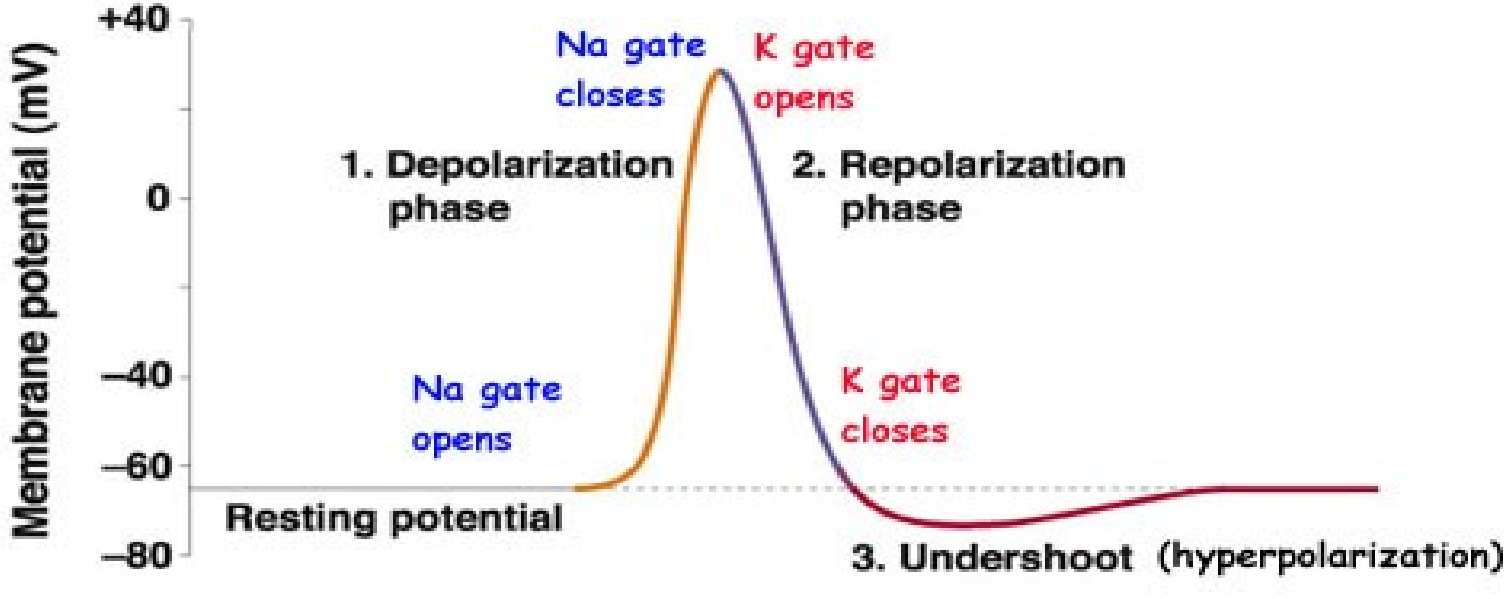
- Atrial syncytium (walls of the atria) and ventricular syncytium (walls of the ventricles).
- Fibrous tissue separates them so potentials are normally conducted only by way of a specialized conductive system (the A-V bundle).
- The atria contract a short time ahead of the ventricles. (allows effective pump action).

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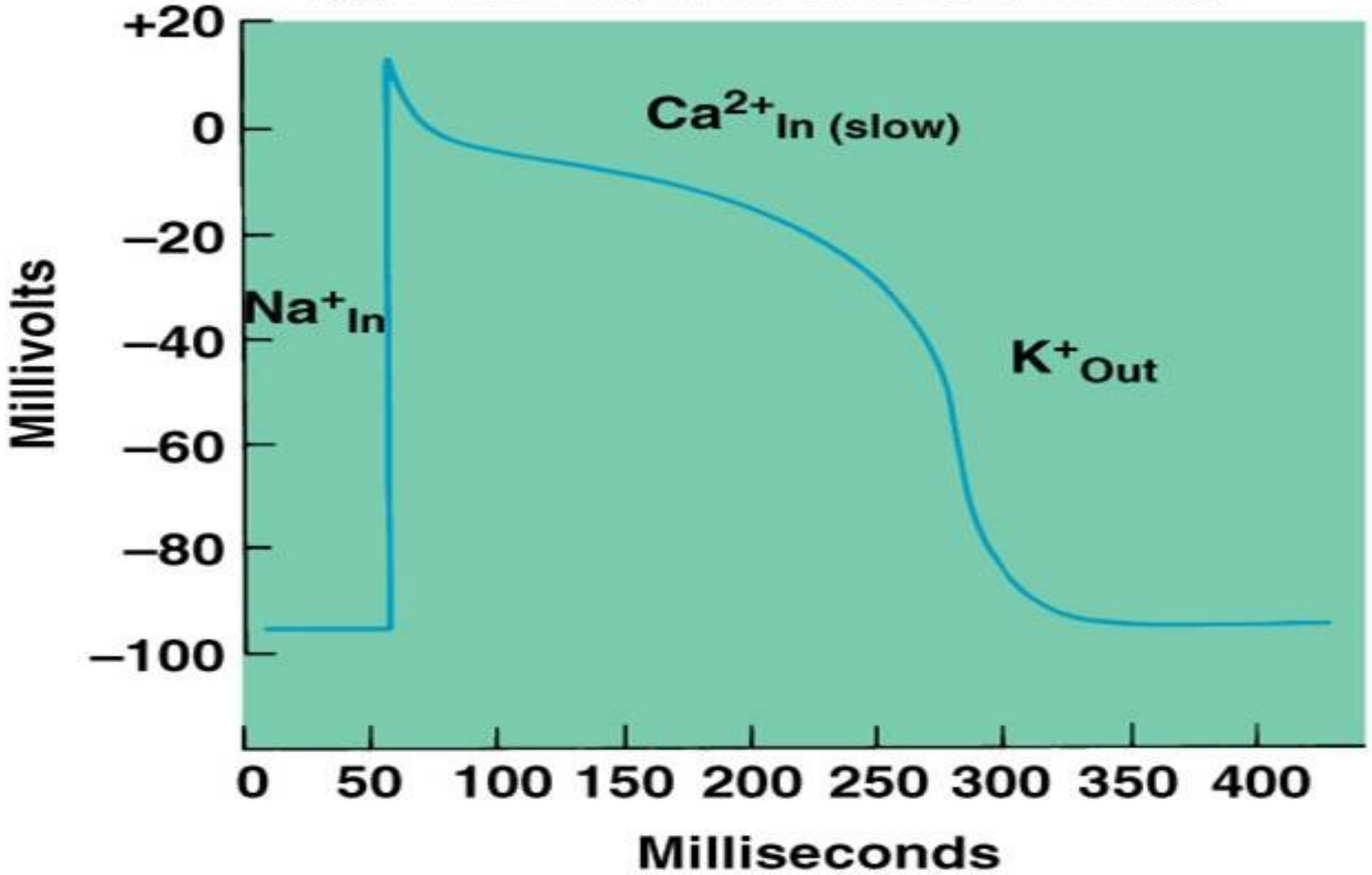
Action Potentials



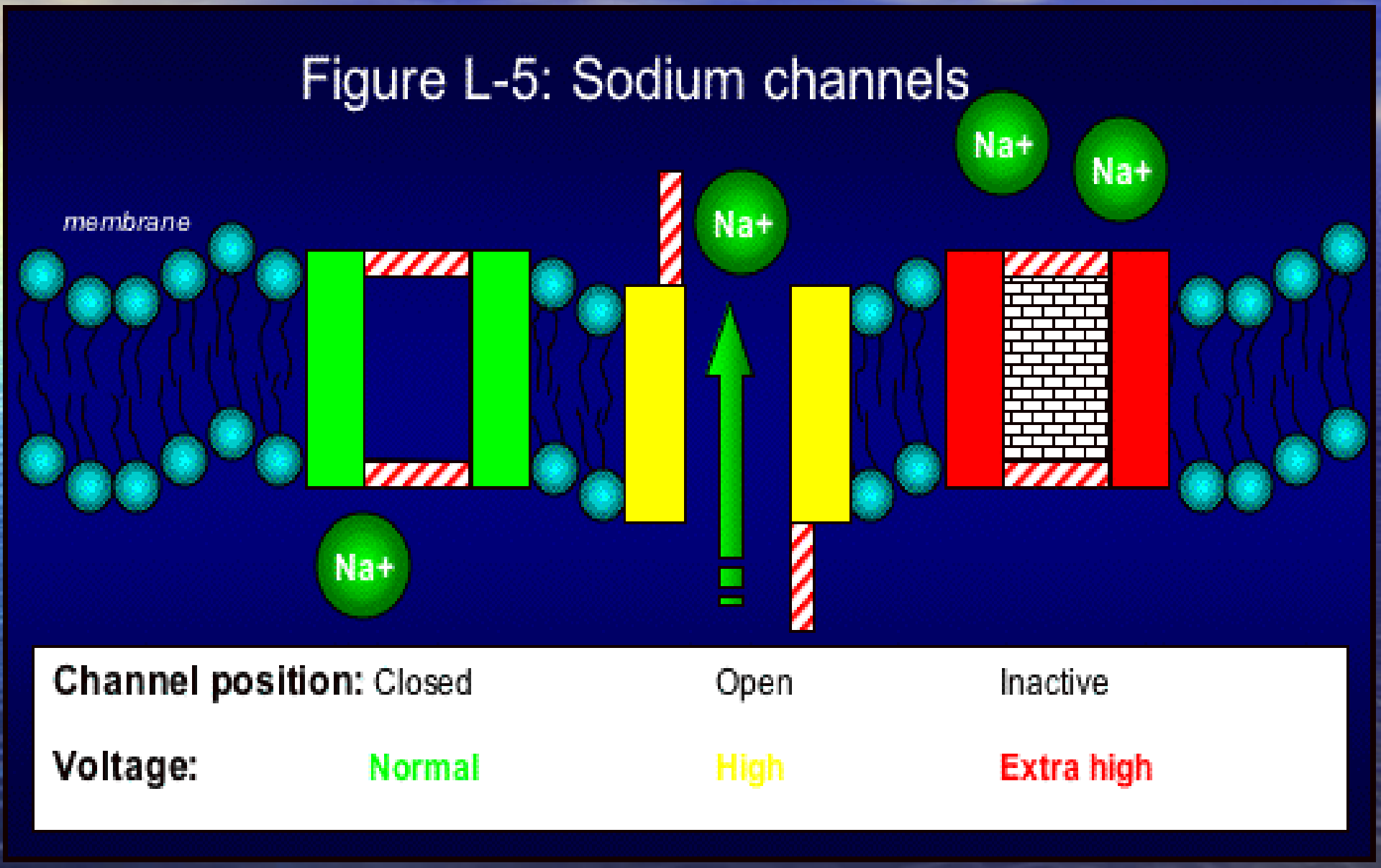


Cardiac muscle action potential

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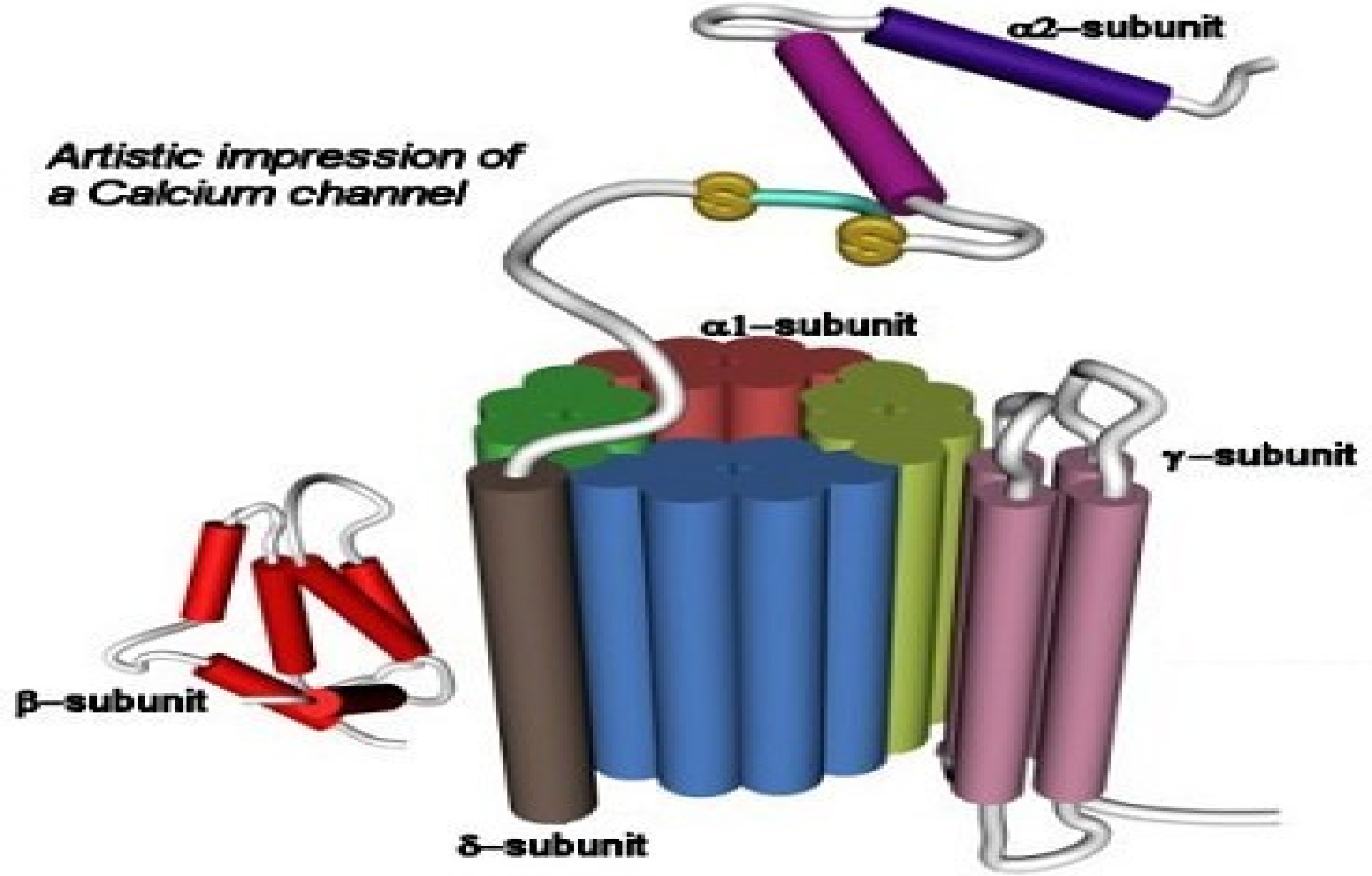
Fast Na channels



Fast Na channels

- Remain open for only a few 10,000ths of a second and then abruptly close.
- Allow tremendous amounts of Na ions to enter the cell.

Slow Ca channels

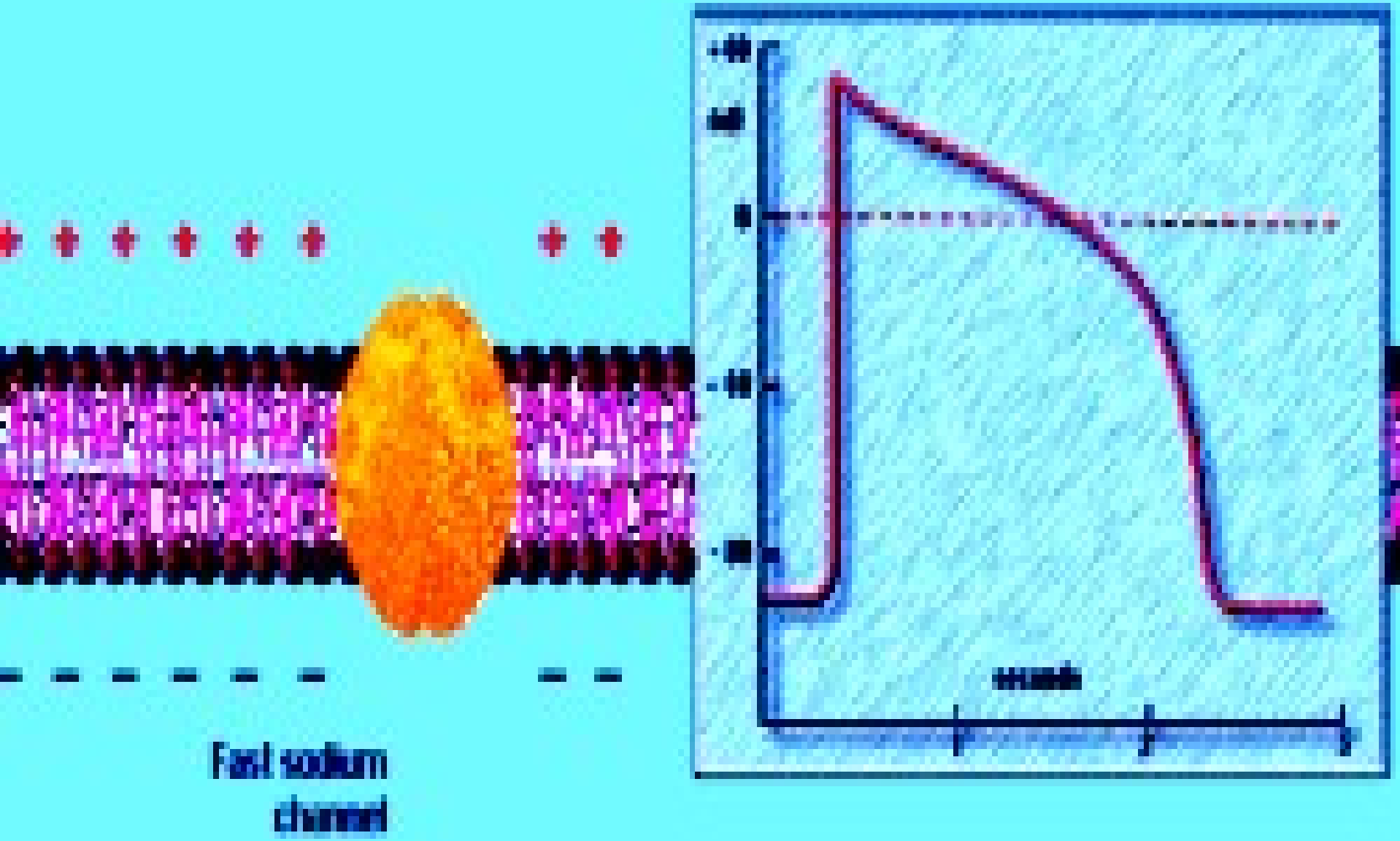


Slow ca channels

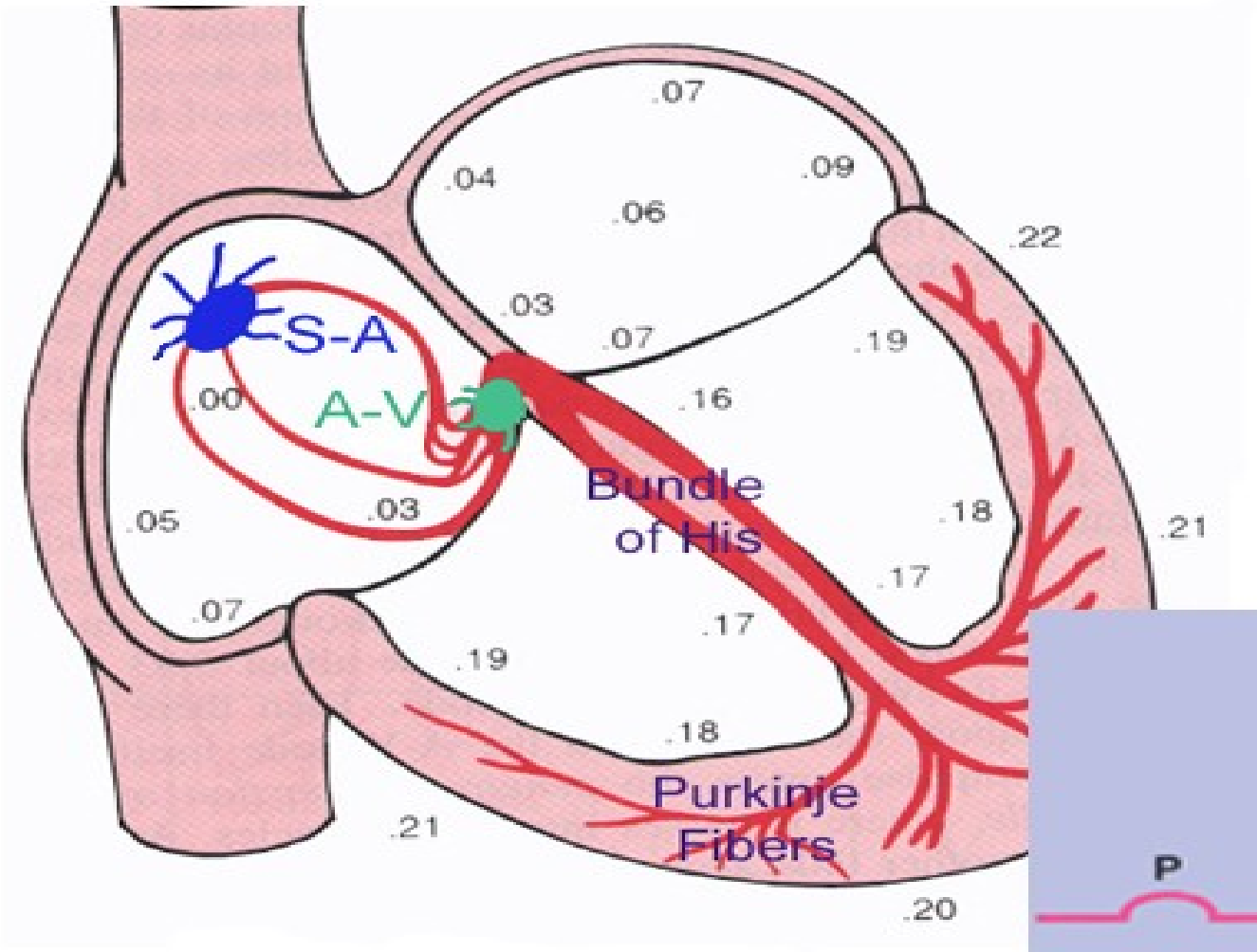
- Slower to open.
- Remain open for several tenths of a second.
- A large quantity of Ca and Na flows through causing:

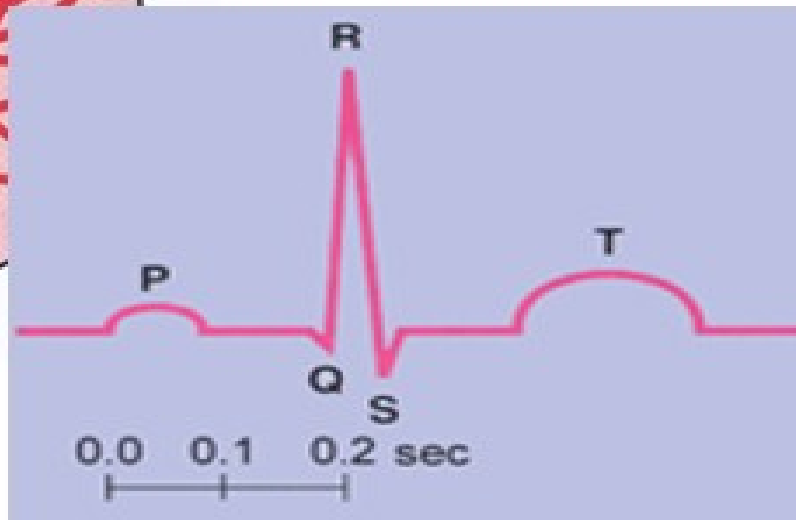
1. The plateau.
2. Help to excite the muscle contractile process.

Depolarization - Initial



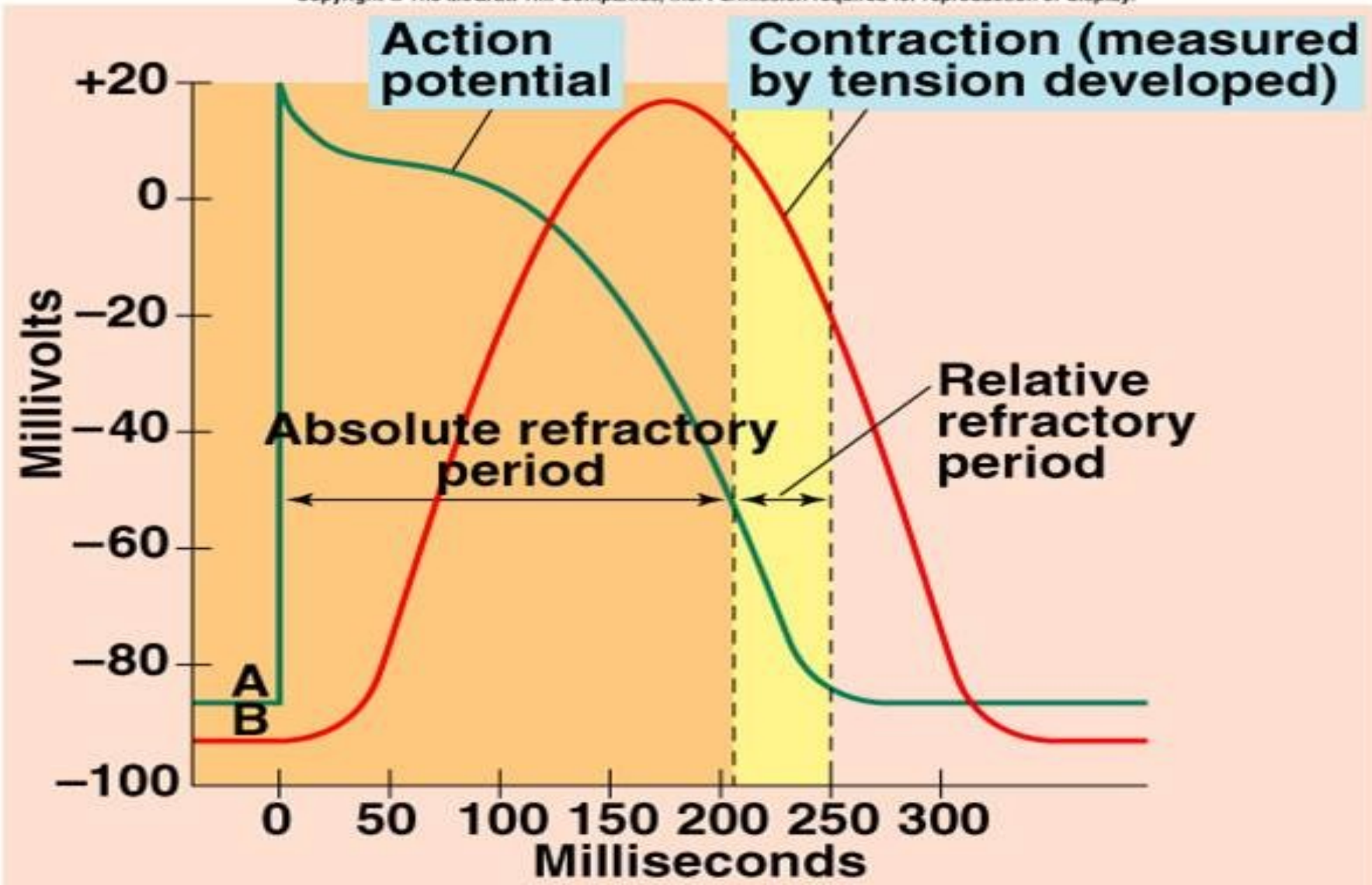
Velocity of signal conduction

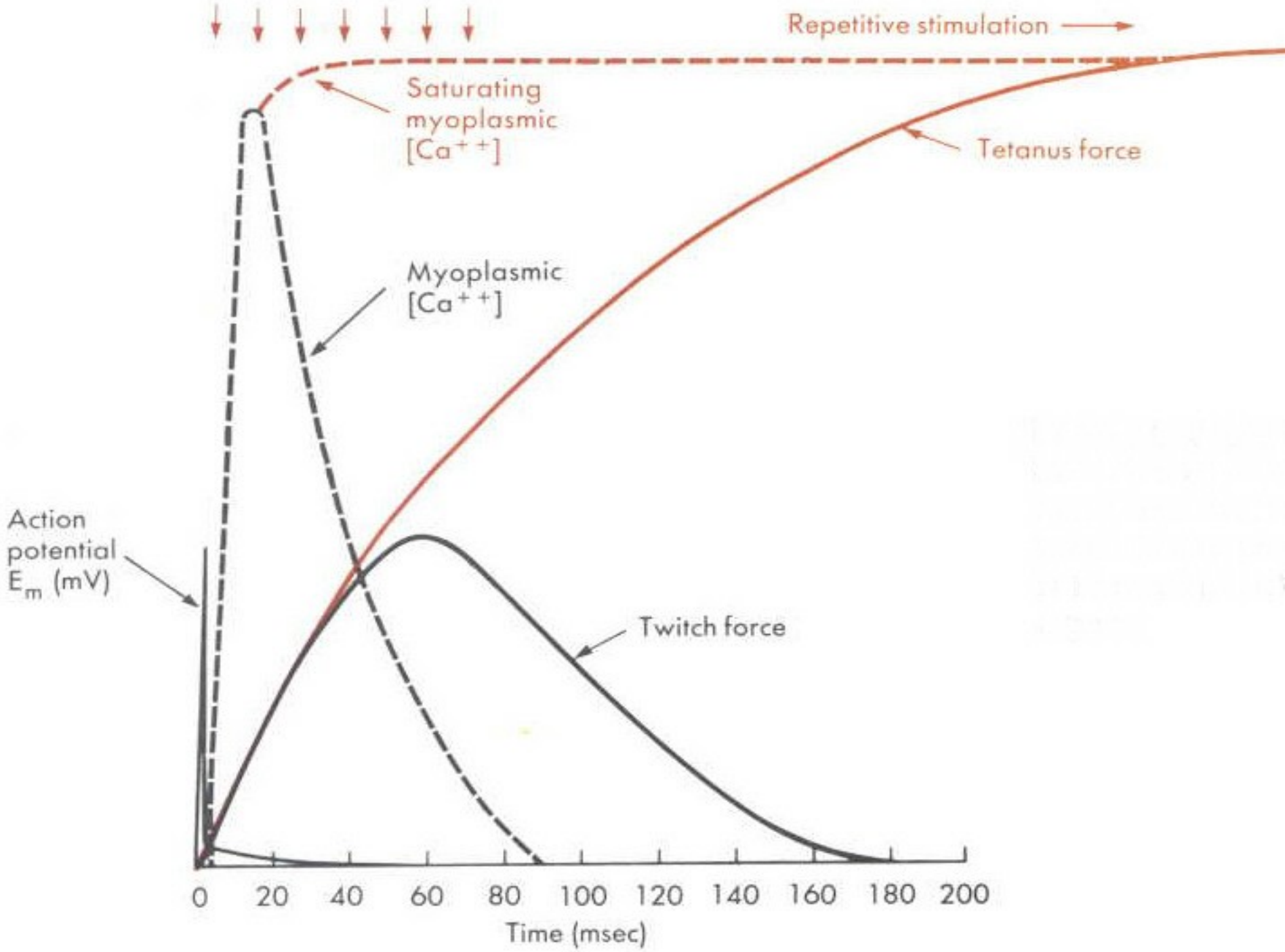




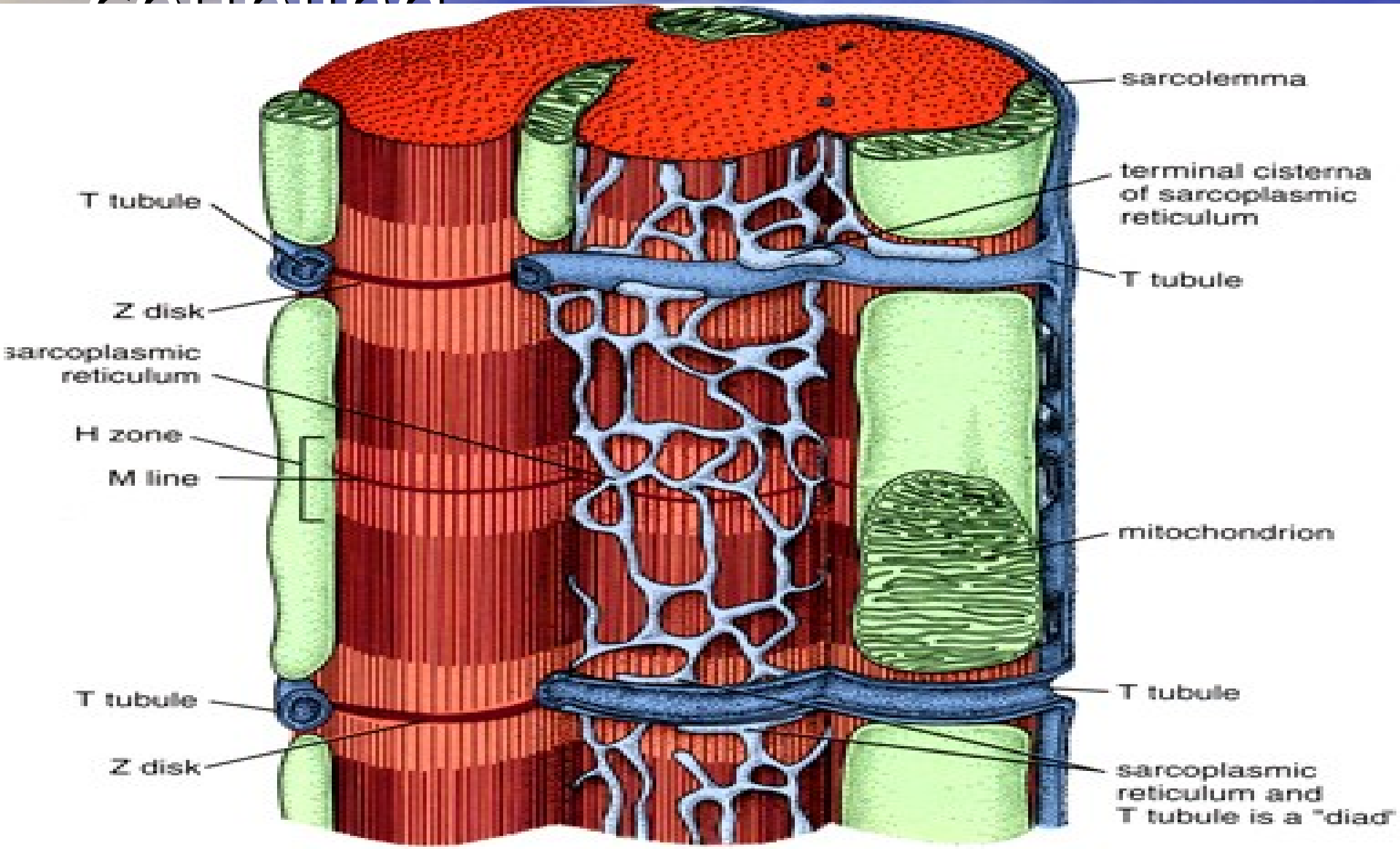
Refractory period

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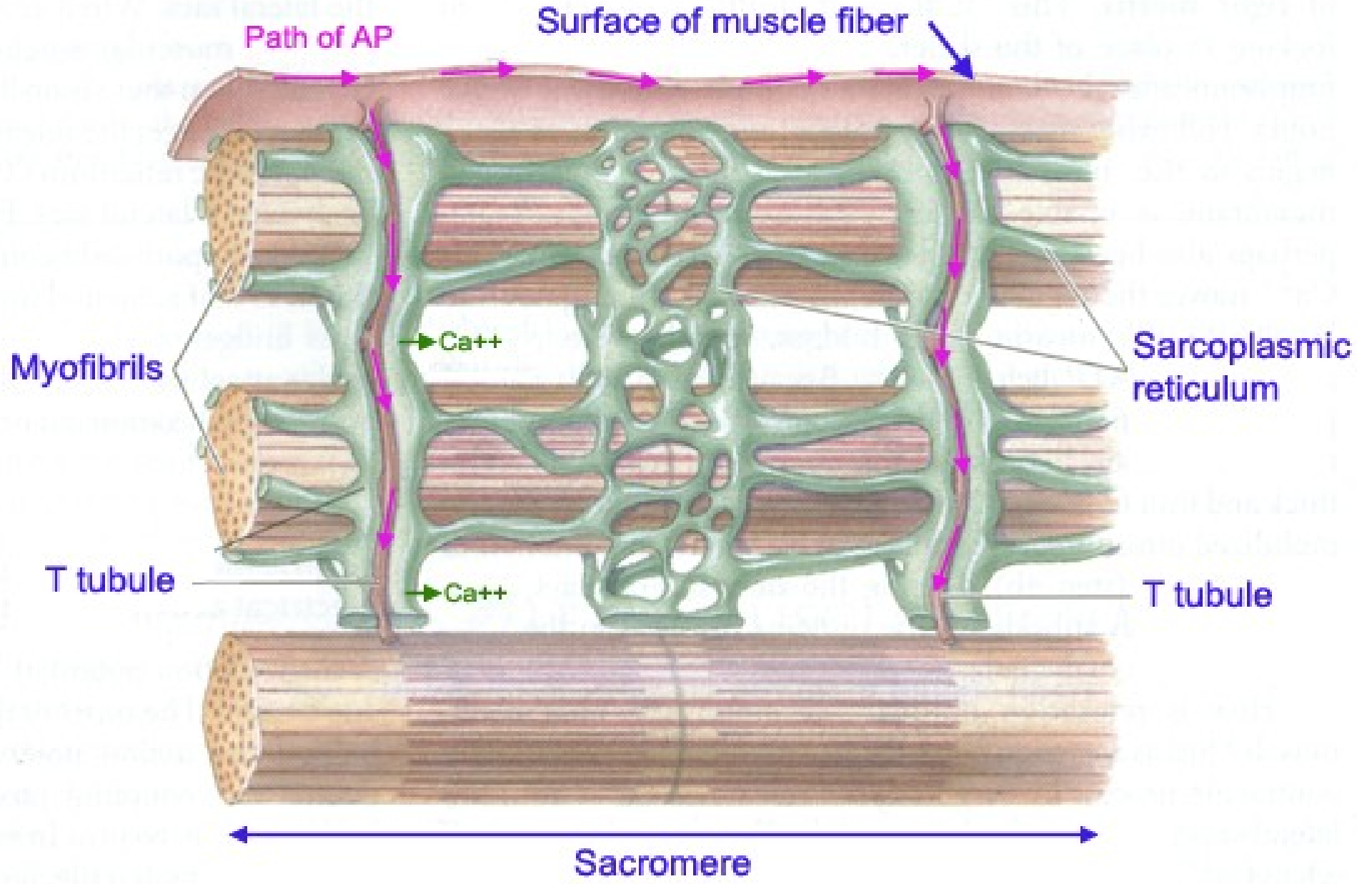


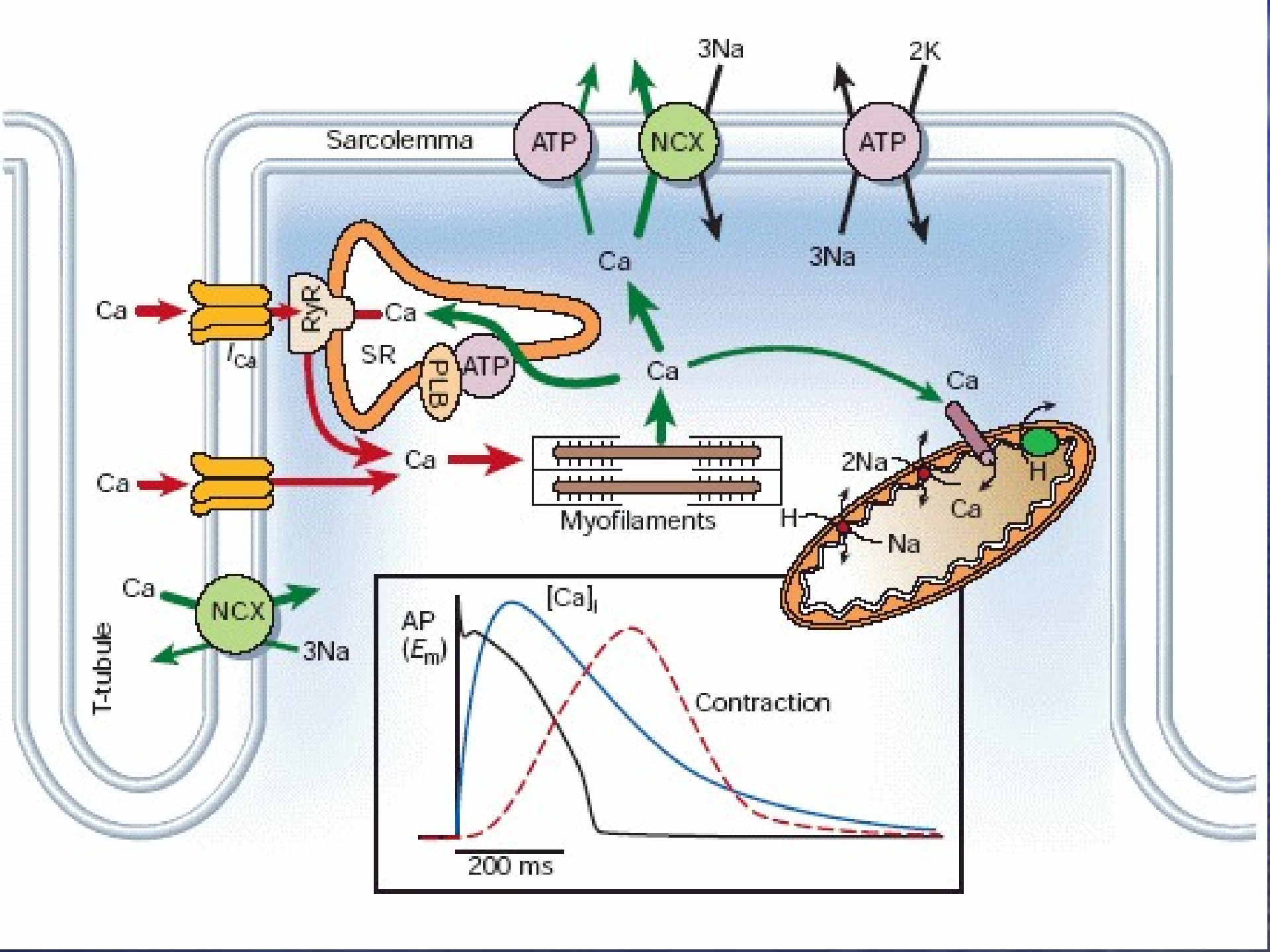

Repetitive stimulation
Saturating myoplasmic [Ca++]
Tetanus force
Myoplasmic [Ca++]
Action potential E_m (mV)
Twitch force
0 20 40 60 80 100 120 140 160 180 200
Time (msec)

Excitation-contraction coupling

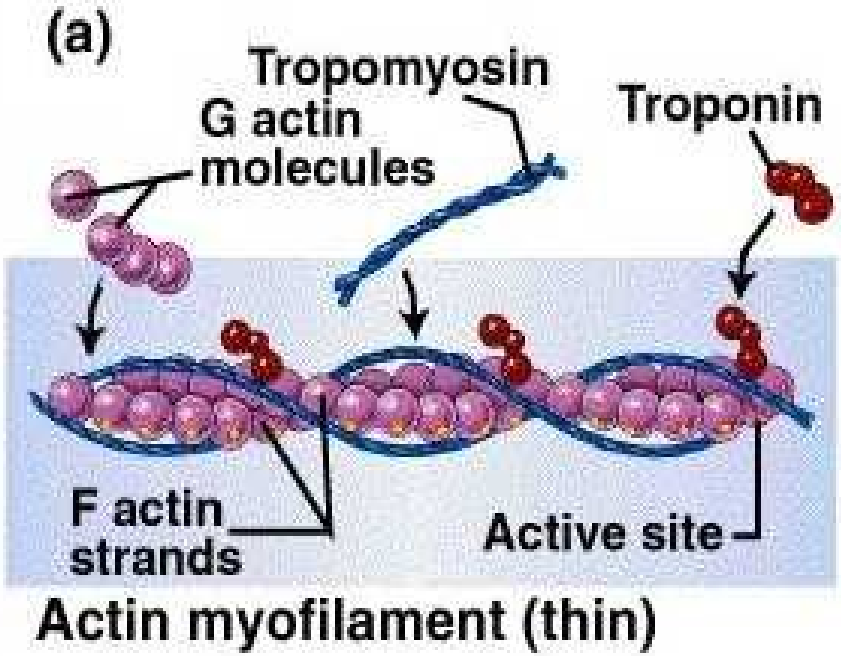


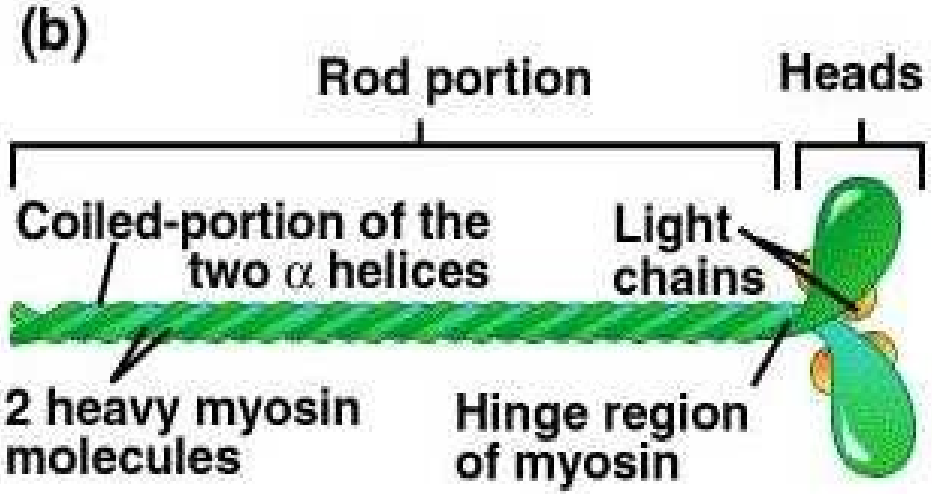
Role of Action Potential and Ca++ in Muscle Contraction

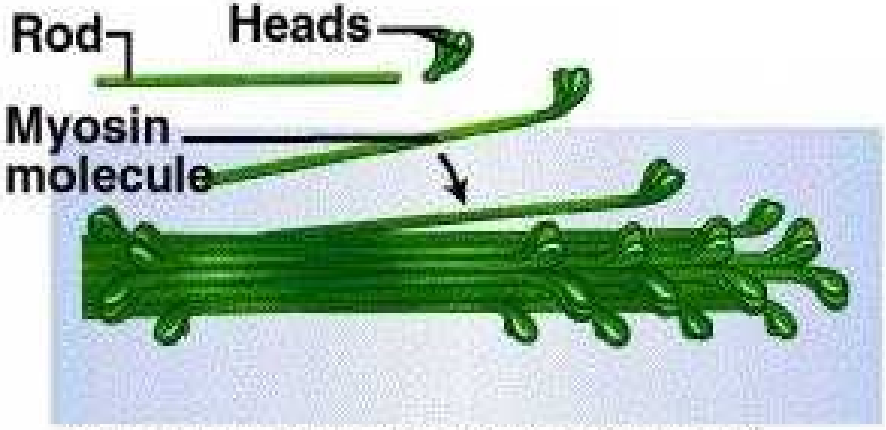


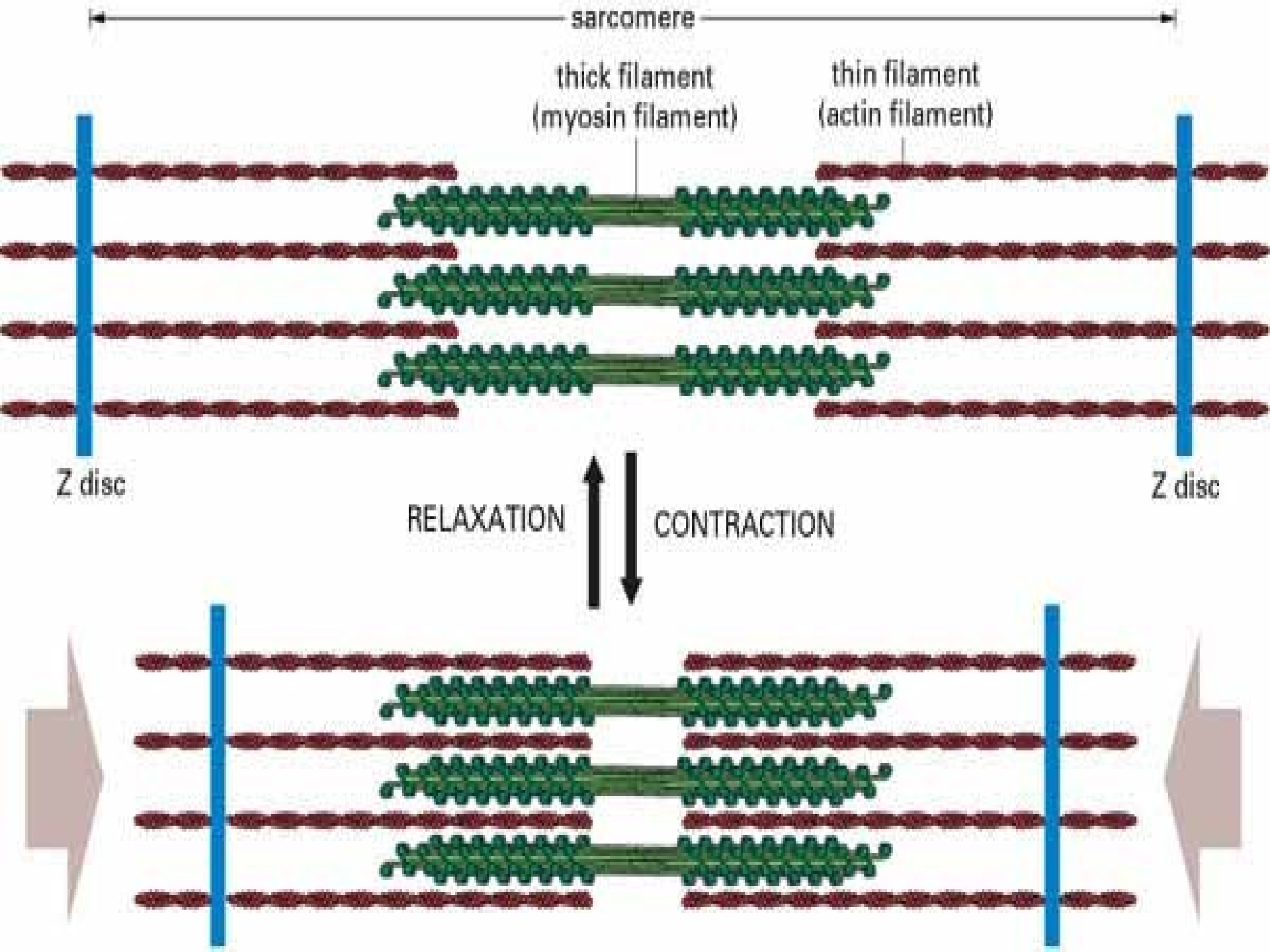

3Na
2K
Sarcolemma
ATP
NCX
ATP
Ca
3Na
Ca
RyR
Ca
SR
PLB
ATP
Ca
Ca
Ca
Ca
2Na
H
Ca
H
Na
Myofilaments
I_{Ca}
Ca
NCX
3Na
T-tubule
AP
(E_m)
$[Ca]_i$
Contraction
200 ms

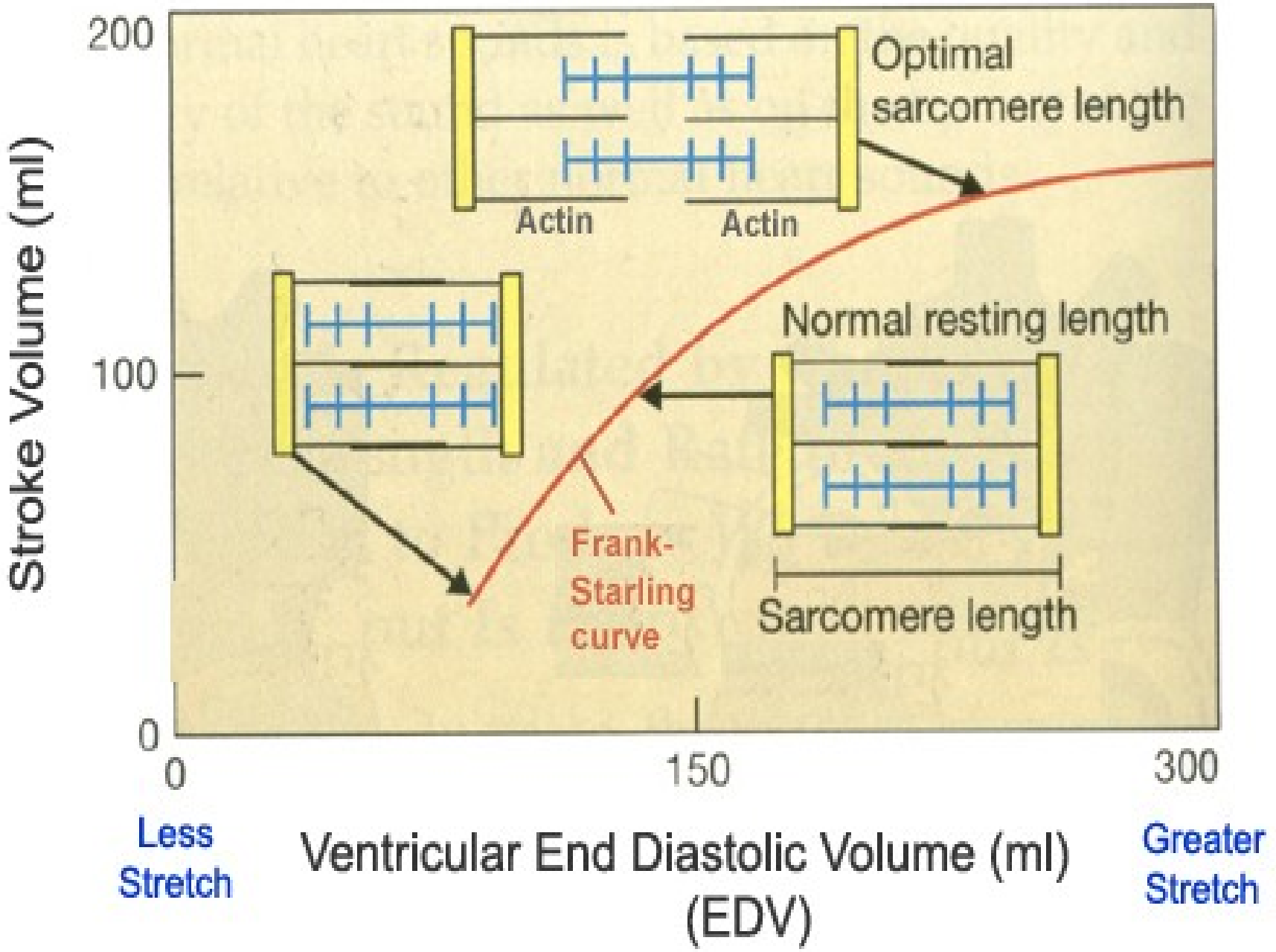
Structure of Actin and Myosin








sarcomere
thick filament
(myosin filament)
thin filament
(actin filament)
Z disc
Z disc
RELAXATION
CONTRACTION

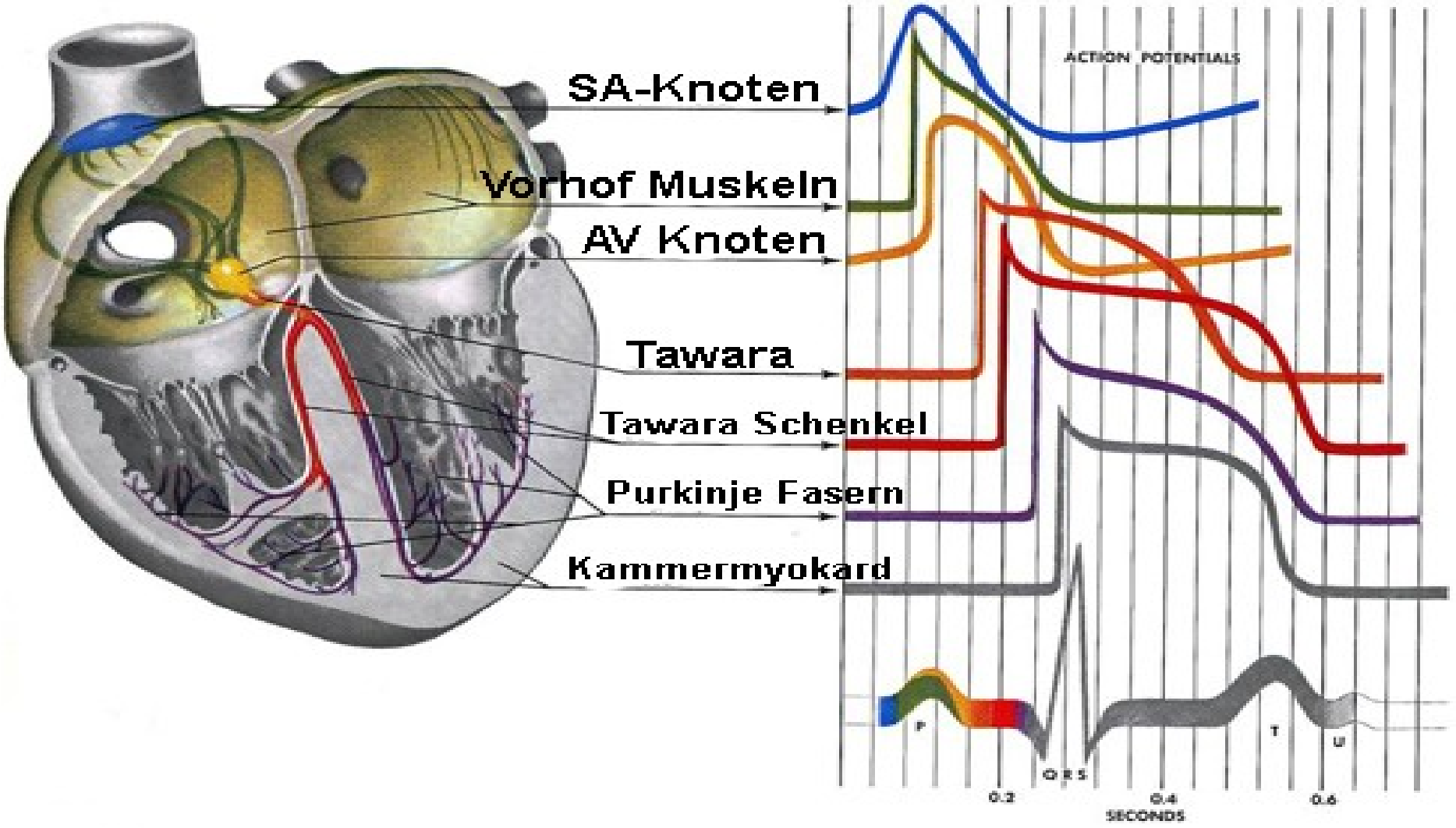

200
100
0
Stroke Volume (ml)
Optimal
sarcomere length
Actin
Actin
Normal resting length
Frank-
Starling
curve
Sarcomere length
0
150
300
Less
Stretch
Ventricular End Diastolic Volume (ml)
(EDV)
Greater
Stretch

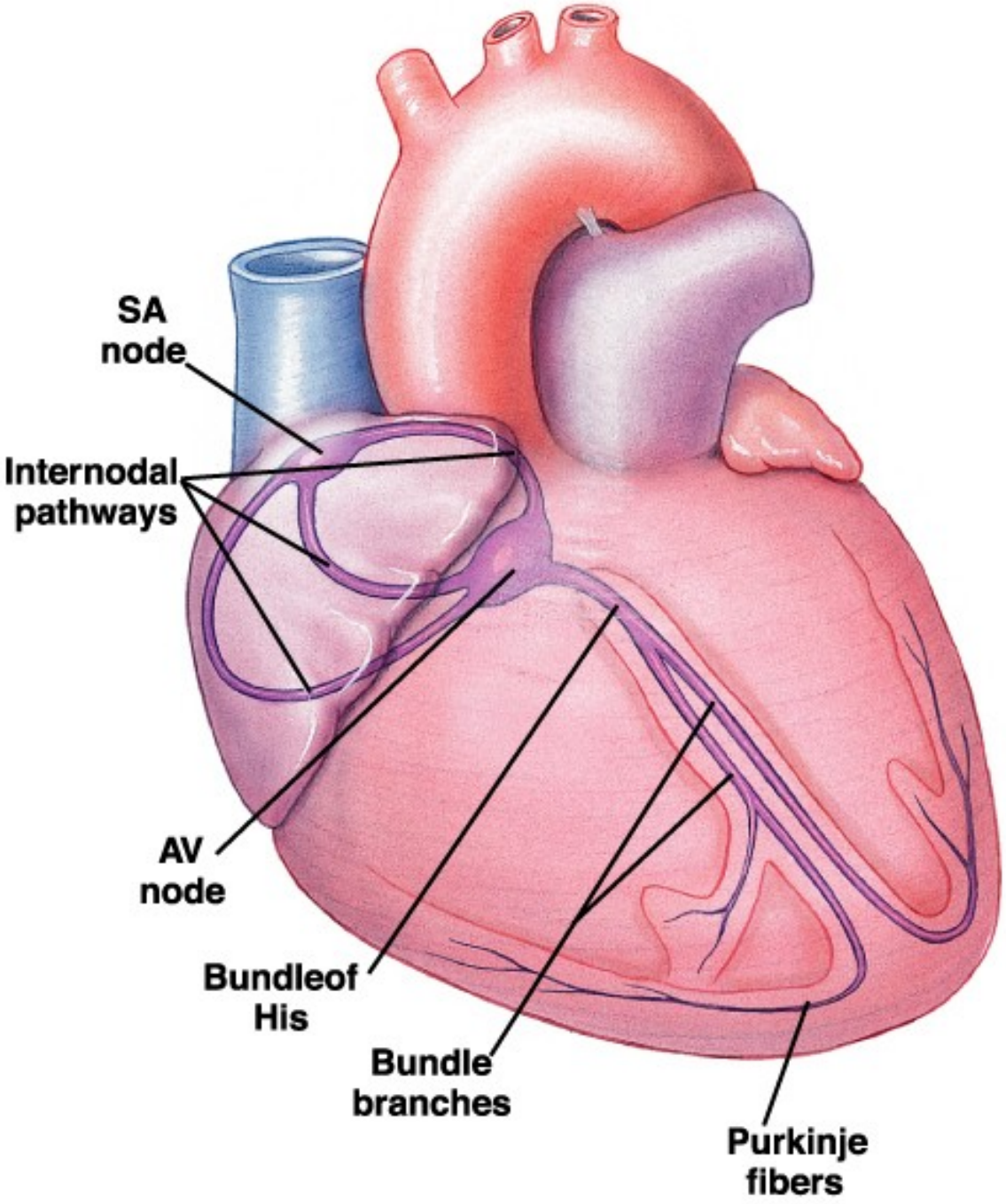
- The strength of contraction of cardiac muscle depends to a great extent on the [Ca] in the extracellular fluid.
- The ends of the T-tubules open directly to the outside of the cardiac muscle fibers.

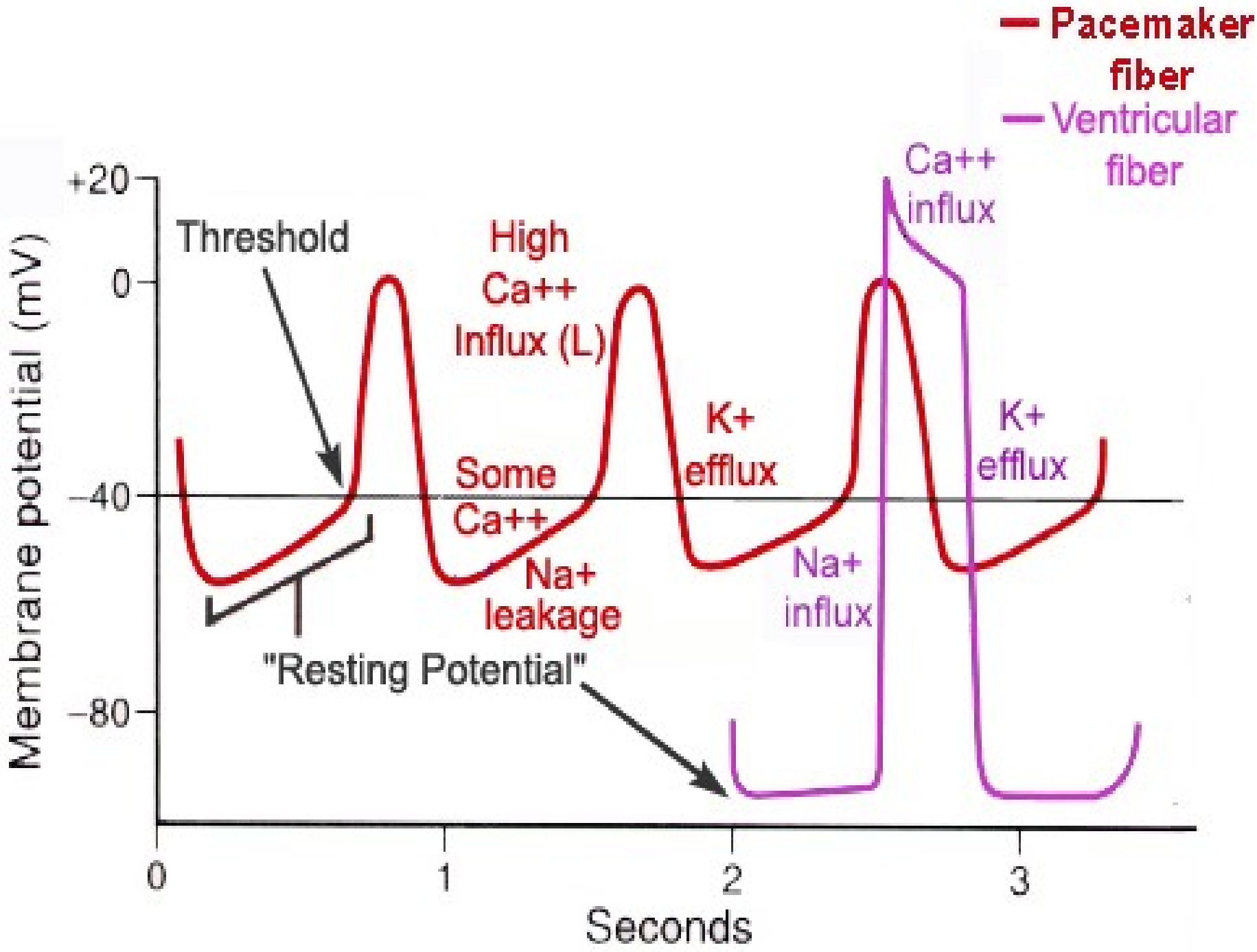
Duration of contraction and effect of heart rate

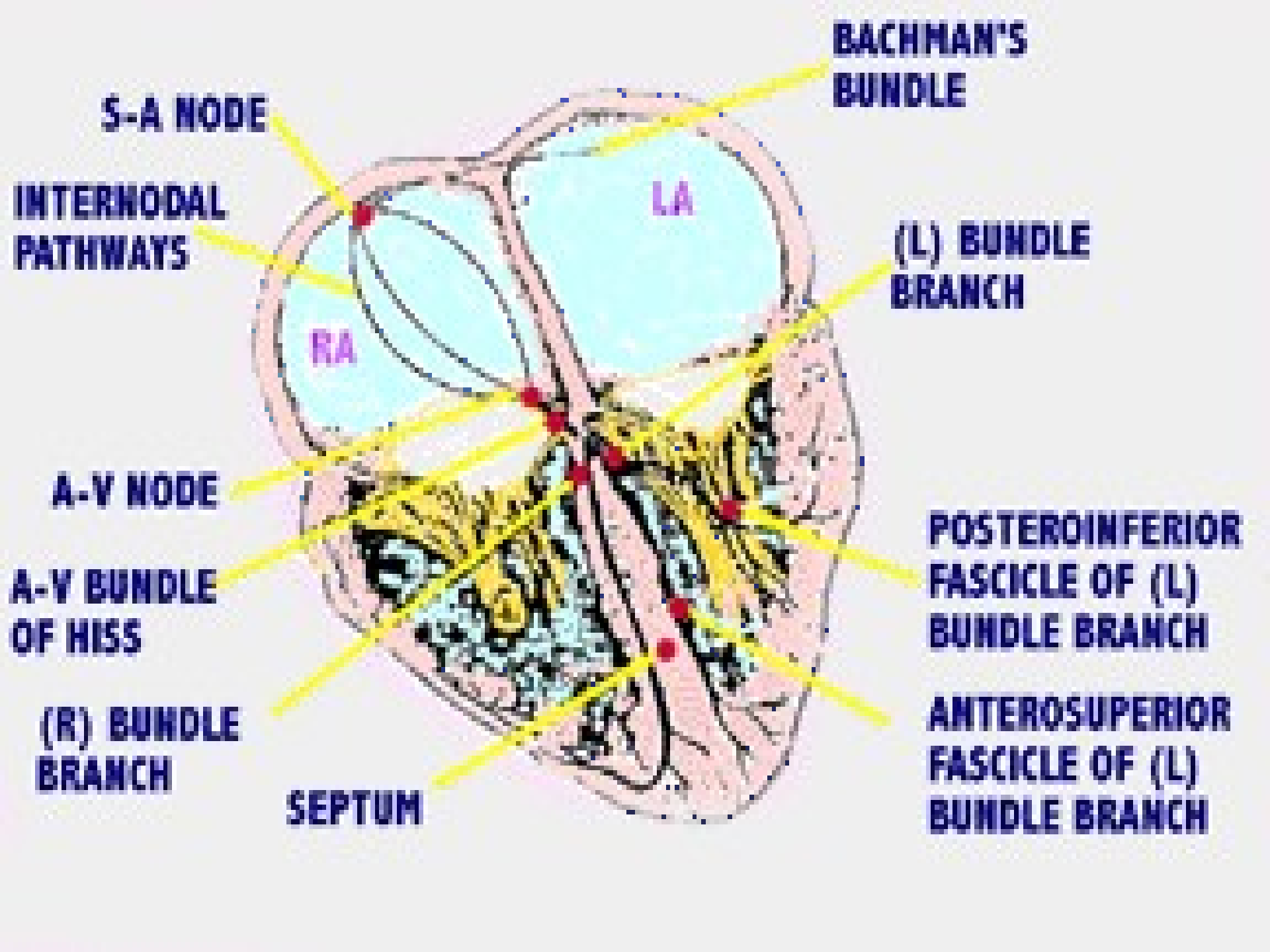
- The duration of contraction of cardiac muscle is mainly a function of the duration of the action potential-about 0.2 sec in atrial muscle and 0.3 in ventricular muscle.
- At 72beats/min the period of contraction is about 40% of the cycle. At 3x normal this period is about 65% and the heart does not remain relaxed long enough to allow complete filling.

Morphology of action potentials of cardiac cells




SA
node
Internodal
pathways
AV
node
Bundleof
His
Bundle
branches
Purkinje
fibers


Pacemaker fiber
Ventricular fiber
Membrane potential (mV)
+20
0
−40
−80
Threshold
High Ca++ Influx (L)
Some Ca++
Na+ leakage
K+ efflux
Ca++ influx
Na+ influx
K+ efflux
"Resting Potential"
0
1
2
3
Seconds


BACHMAN'S BUNDLE
S-A NODE
INTERNODAL PATHWAYS
LA
RA
(L) BUNDLE BRANCH
A-V NODE
A-V BUNDLE OF HISS
POSTEROINFERIOR FASCICLE OF (L) BUNDLE BRANCH
(R) BUNDLE BRANCH
SEPTUM
ANTEROSUPERIOR FASCICLE OF (L) BUNDLE BRANCH

Thank you