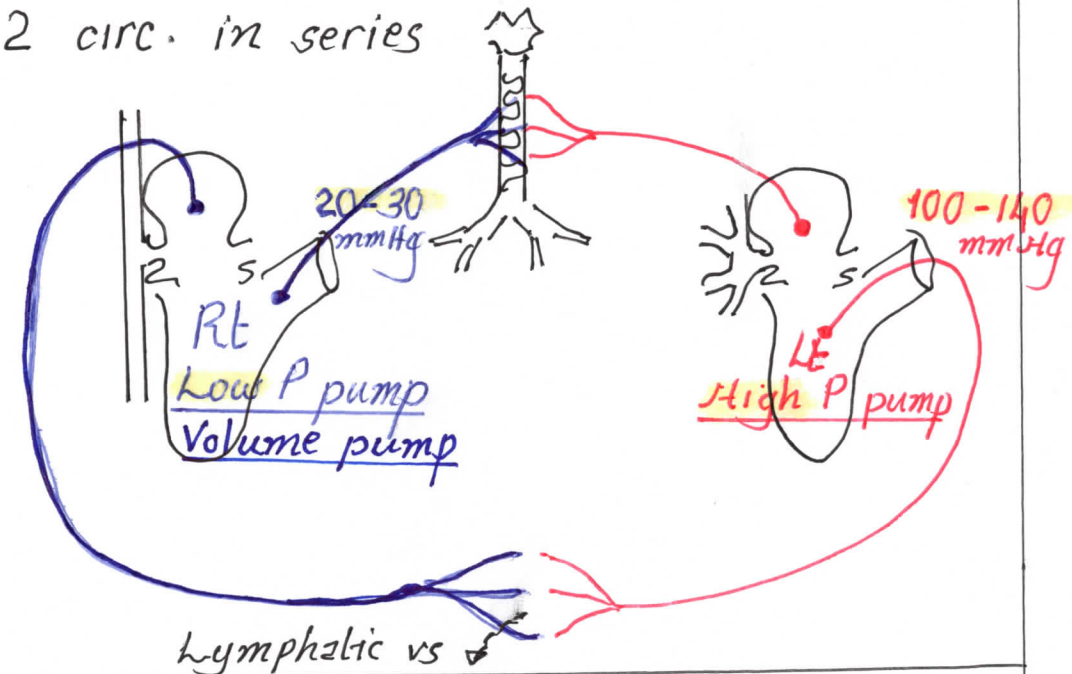
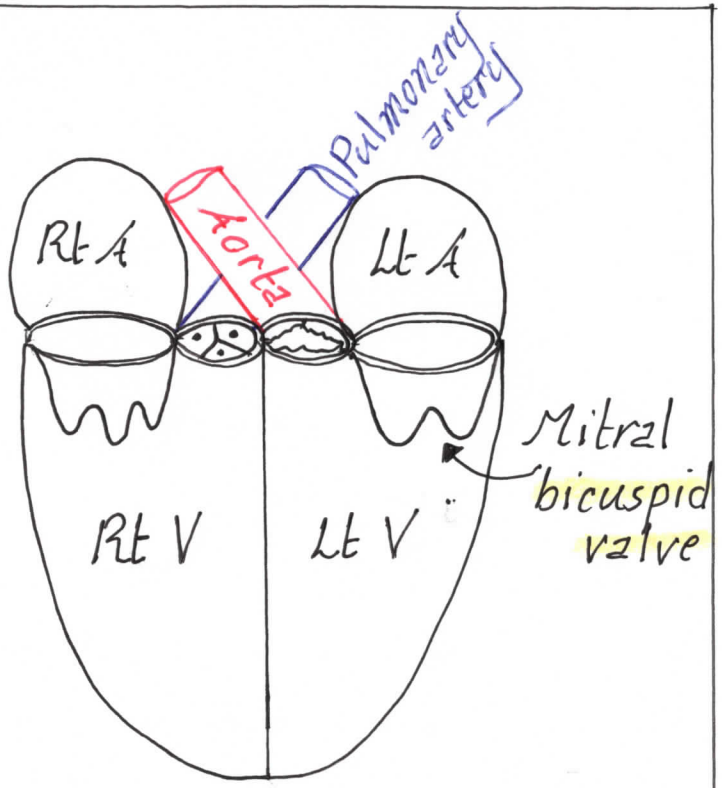
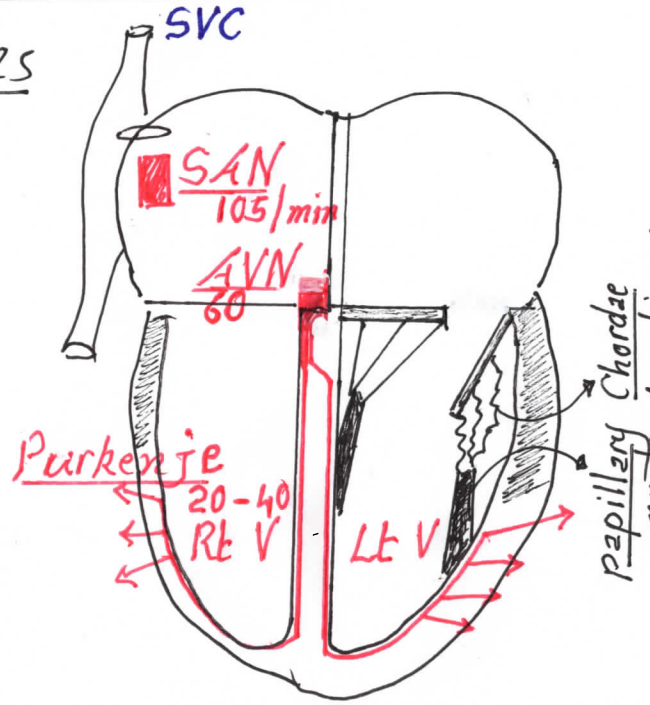
CVS = Heart + bl vessels 2

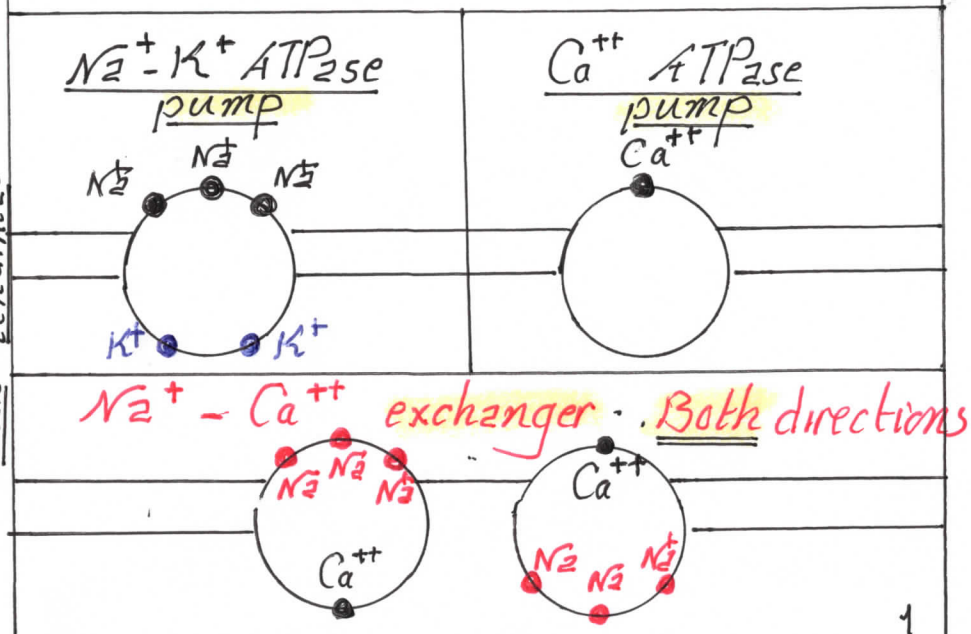
2 circ. in series



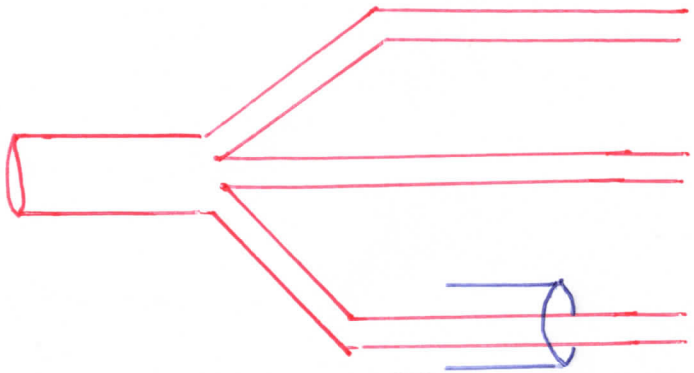


2 circulations
2 Hearts
2 Chambers
2 Types of valves
2 Types of m. fibres
2 Syncitia

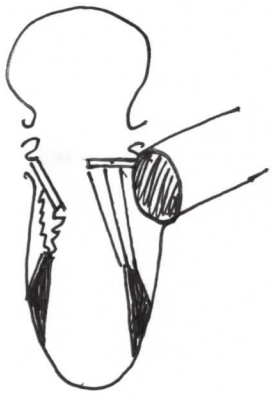


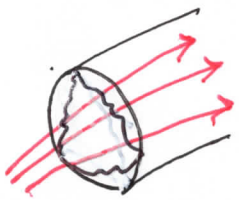


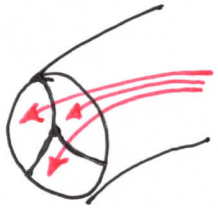
Bl vessels parallel
(not in series)



except Liver . Hepatic artery
From Aorta
Portal vein
From GIT

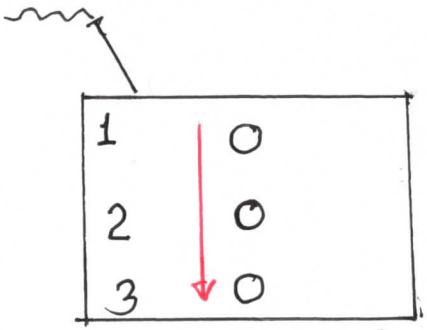




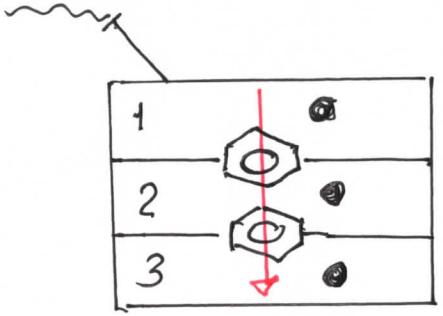


Semilunar valves

Aortic & Pulmonary



Anatomical



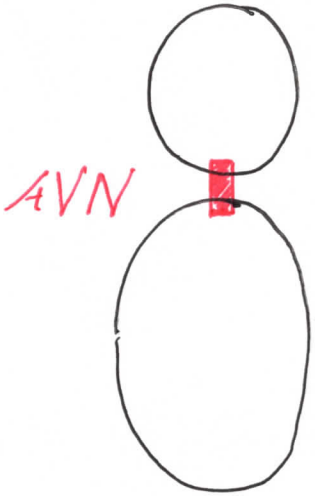
Functional

syncitium

Gap junction
intercalated discs

Heart

2 functional syncitia



Atrial syncitium

Ventricular syncitium

Excitability

A potential of atrial or ventricular muscle fibres

- **Fast** response AP
- **Nonpace maker** AP

⓪ **Rapid** Dep

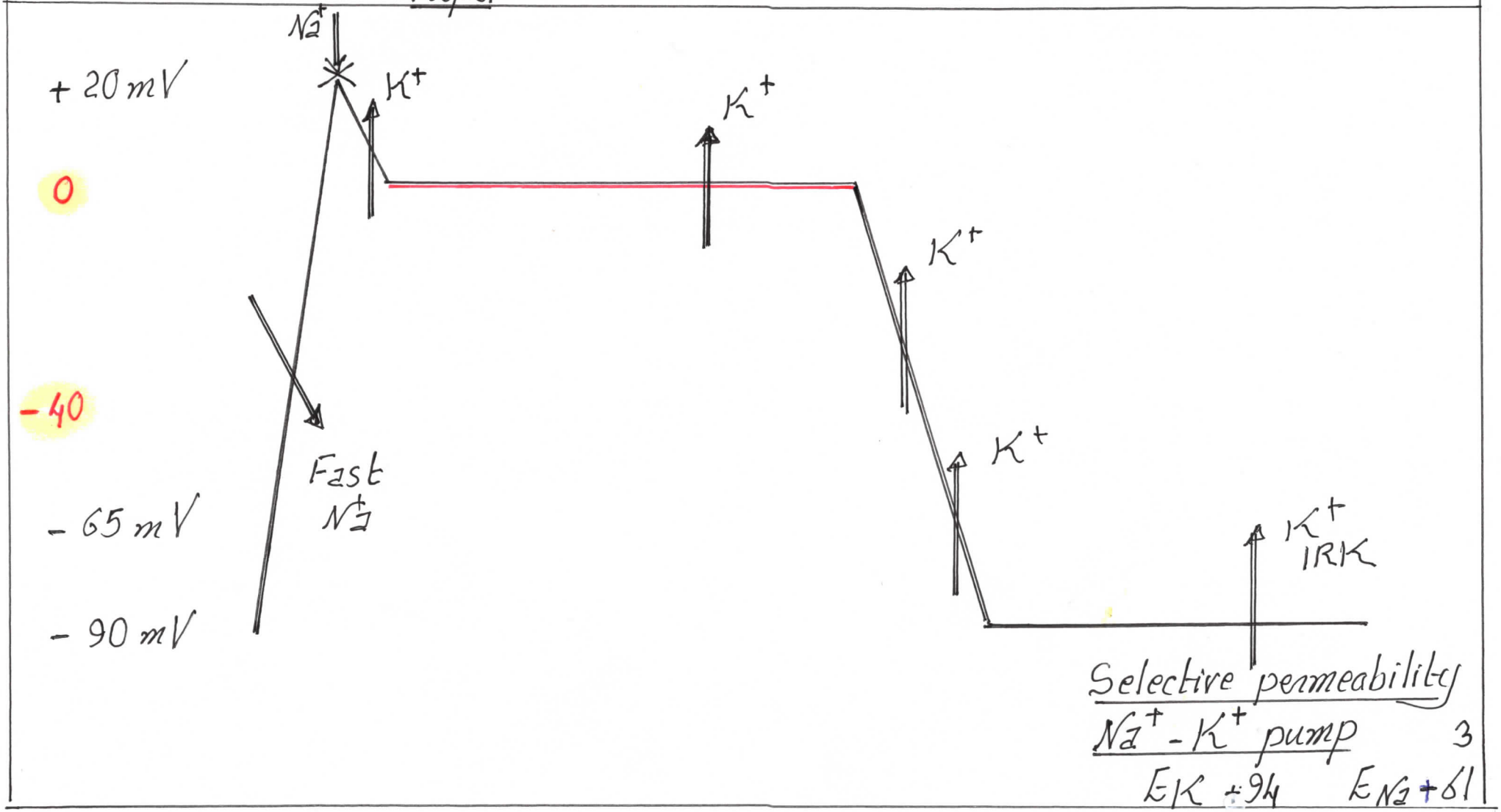
① rapid small initial Repol

② **Plateau**

③ rapid large Repol

④ **RMP**

no Hyperpolar



Selective permeability

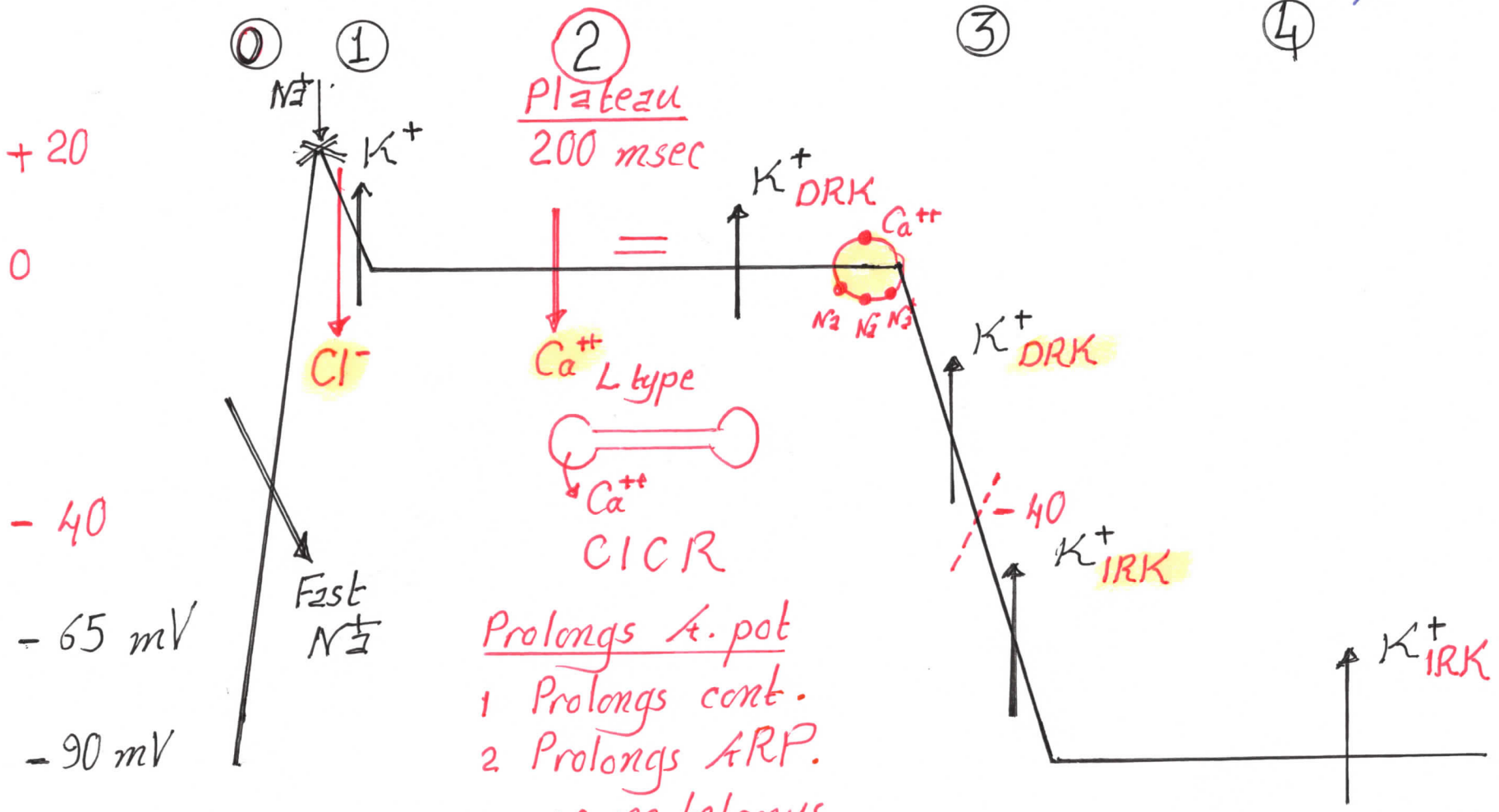
$Na^+ - K^+$ pump 3

E_K +94 E_{Na} +61

Excitability

A Potential of atrial or ventricular muscle fibres

Fast response A pot



Prolongs A. pot

1 Prolongs cont.

2 Prolongs ARP.

i.e no tetanus

Ca^{++} L type

starts phase 0 -40 mV

Fully active phase 2

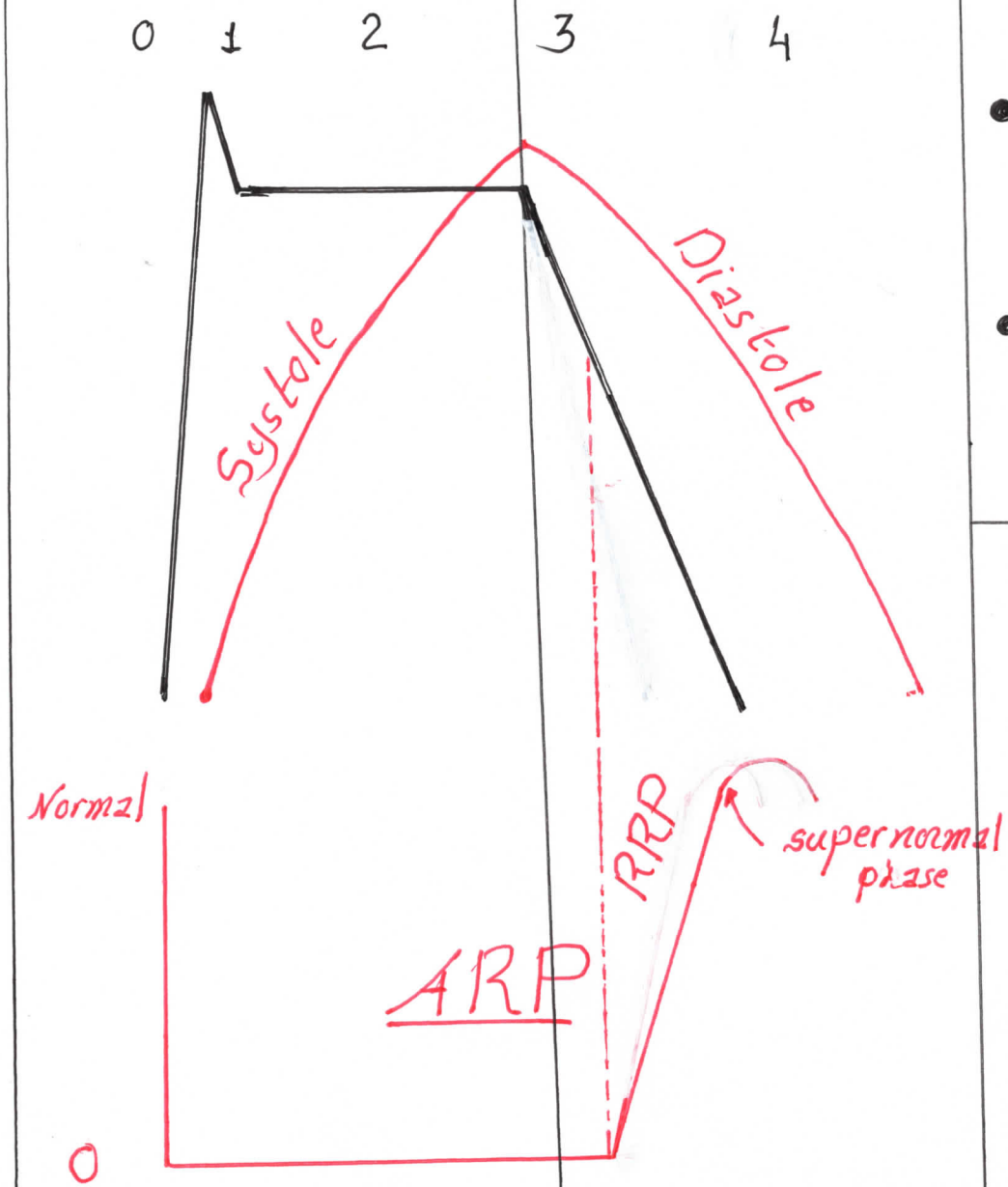
inactivated at end of phase 2

Selective permeability

$Na^+ - K^+$ pump

E_K - 94 mV

E_{Na} + 61 mV



Mechanical changes

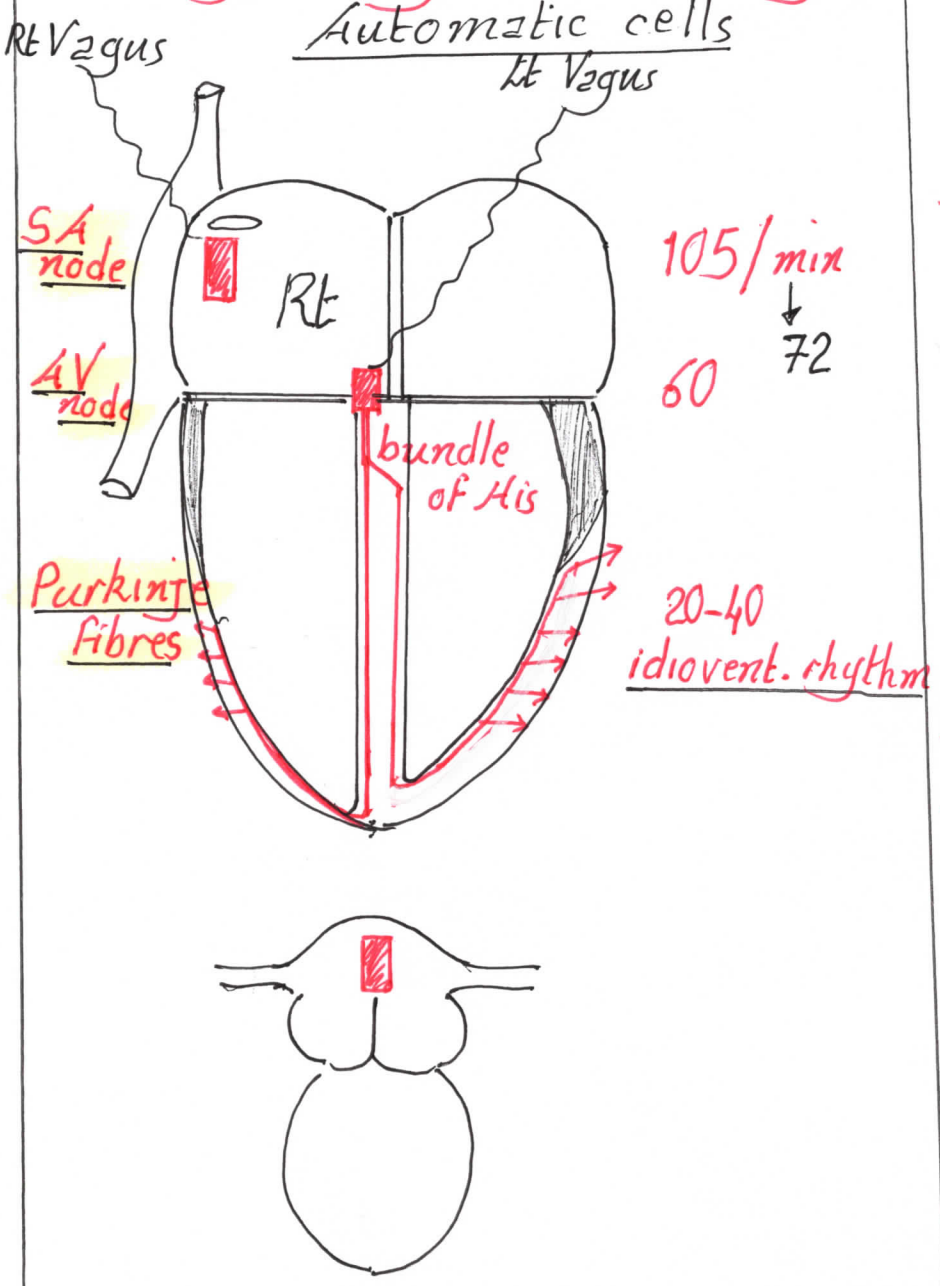
- **Systole**
  - begins immediately after depol
  - ends by end of plateau
- **Diastole** double time of 3rd phase

Mechanical 1½ time Electrical (AP)

Excitability changes

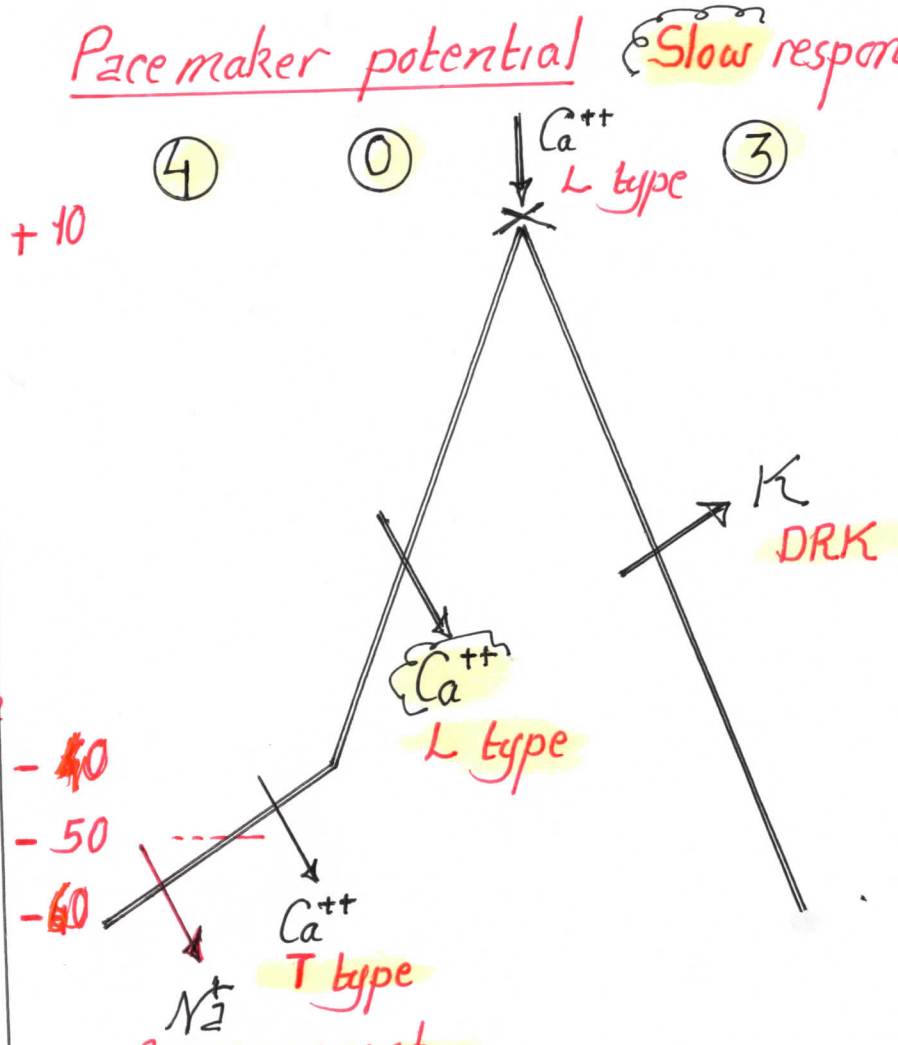
- **ARP** excitability = 0
  - coincides 0, 1, 2 early part 3
  - i.e covers whole period of Systole + early diastole
  - This prevents tetanus
- **RRP** excitability below normal (allows filling)
  - coincides with rest of phase 3
- **Supernormal phase of excitability**
  - vulnerable phase
  - Late part of phase 3

Rhythmicity (Automaticity)



Pace maker potential

Slow response Apot



prepotential

Spontaneous gradual depol

Spontaneous slow DIASTOLIC depol

notes stable
No RMP
No Plateau

Factors affecting rate of discharge of SAN (rhythmicity or HR):

① Autonomic nerves

Sympathetic ⟶ ++ i.e tachycardia
+ve chronotropy

Mech Noradrenaline (Norepinephrine)
β_1 ⟶ ++ cAMP
++ funny current
++ slope of phase 4
reach threshold " 0
in a shorter time.

Parasympathetic ⟶ -- i.e bradycardia
-ve chronotropy

Mech Acetylcholine
a Muscarinic R ⟶ -- cAMP
b Activates K_{ACh} channels
++ K efflux
antagonises funny current
-- slope of phase 4

② Catecholamines = Symp. n.s

③ Body temp
1 °C ⟶ 10 beats/min

④ Extracell K
a ↓ K^+ ⟶ ↑ HR ++ slope phase 4
by -- K^+ conductance in SAN
b ↑ K^+ ⟶ ↓ HR

⑤ Calcium channel blocking drugs
↓ HR & ↓ contractility
by inactivating Ca^{++} L type.

Non pacemaker (Atrial & Vent) A potent.

Fast response A pot.

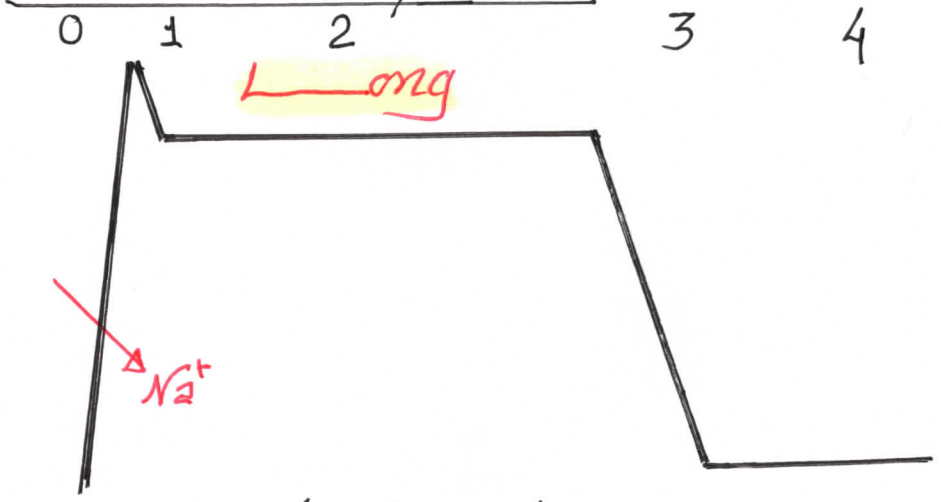
Na^+

Pace maker (SAN & AVN) A. potent

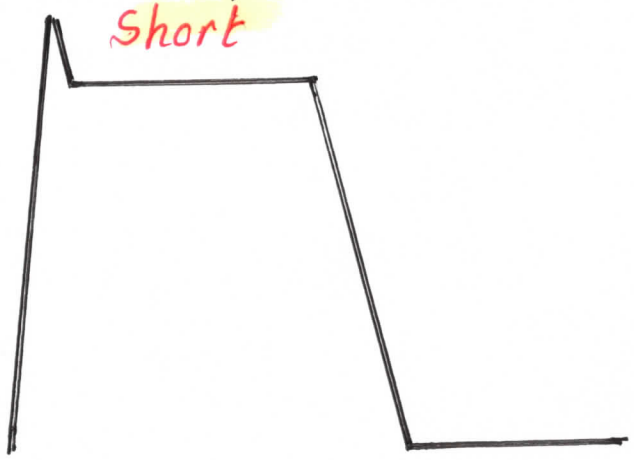
Slow response A pot.

Ca^{++}

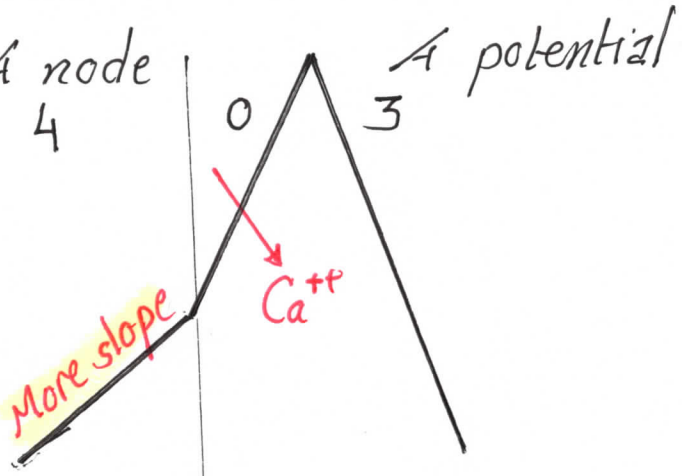
Ventricular A potential



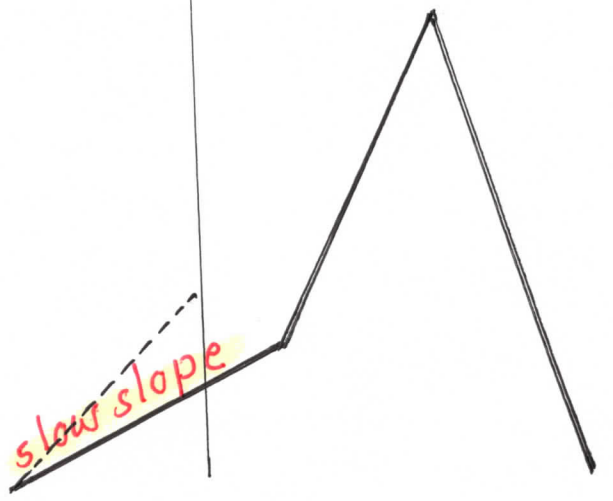
Atrial A potential



SA node A potential



AV node A potential.



Conductivity

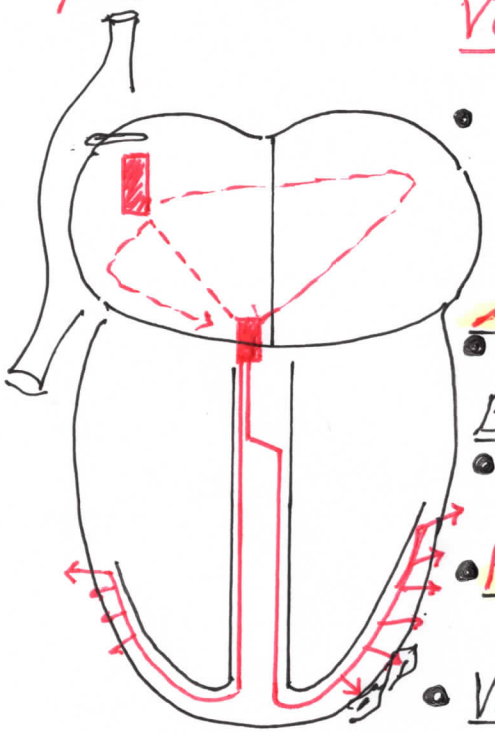
Velocity of conduction depends on :

1. Number of Gap junctions
   - Note Ability to allow current flow
     - is decreased by ↓O_2 & ↑Ca^{++} in myocytes
2. Amplitude & speed of upstroke of A potential

Factors affecting velocity of conduction

1. Autonomic nerves
   - Sympathetic
     - Norepinephrine β_1
     - ++ rate of conduction
     - Mech Faster upstroke
   - Parasymp
     - Acetylcholine Muscarinic R
     - -- rate of conduction
     - Mech Slower upstroke
2. Drugs Digitalis
   - Stimulates parasymp.

Propagation of Cardiac impulse



Velocity in meter/sec

- Atrial myocytes 0.5
- Internodal bundles 1
- AV node 0.05 Slowest
- Bundle of His. & Rt & Lt bundles 2
- Purkinje F 4 Fastest
- Vent myocytes 0.5

AV node	Purkinge Fibres
SLOWES	FASTEST

Few	Gap junctions	Many
Slow	Upstroke of AP	Rapid

1. Delays vent. cont till end of A emptying
2. Protects vent. against High path. A rhythms

Importance: To excite all vent fibres at one time & as one unit → forcible cont

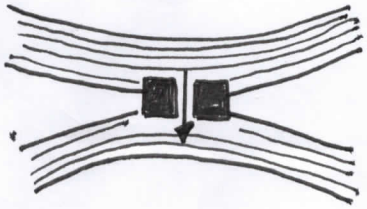
Myocardial properties

- Structure of cardiac myocyte (muscle fibre)
  Length 100 μ & diameter 25 μ.

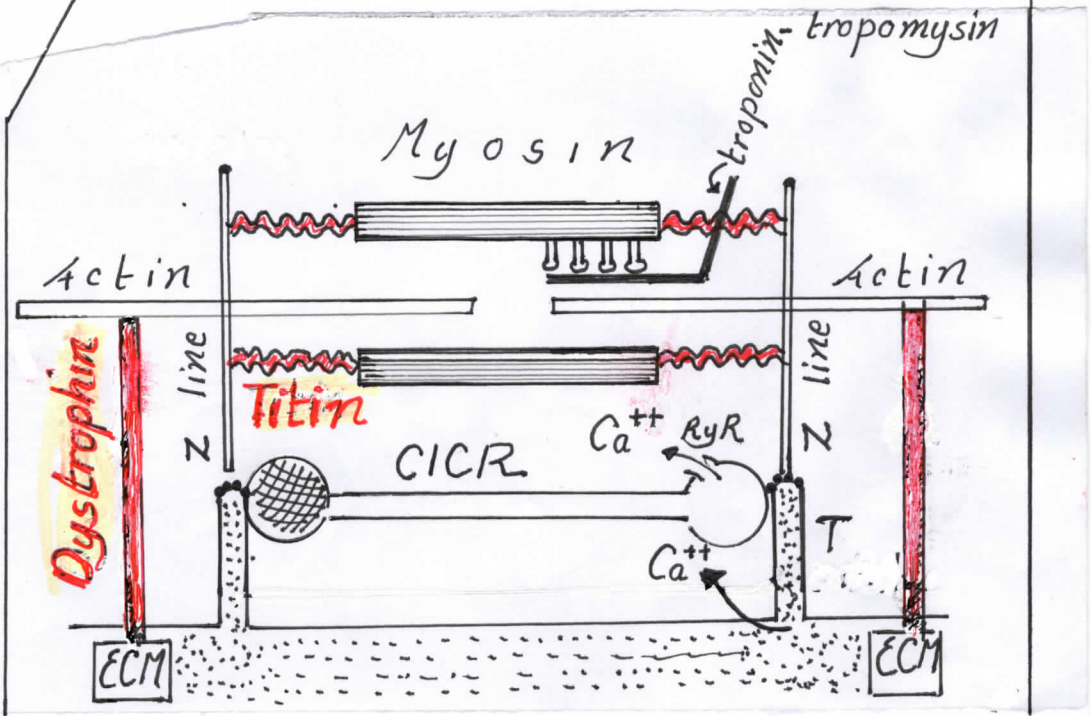
Resembles

Smooth muscle — Syncitium

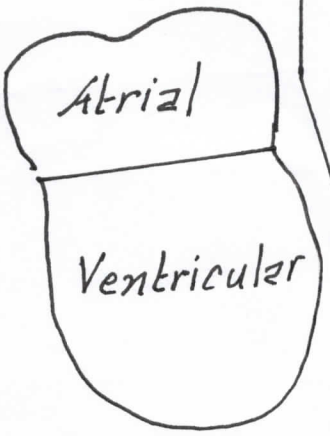
Skeletal muscle — Striated



Intercalated disc
Gap junction



2 functional syncitia



- T tubule at Z line

(connectin)

- Titin Giant filamentous elastic ptn
  Connects myocin to Z line.
  Elasticity of myocytes → passive mechan. properties
- Dystrophin Rod shaped Ptn.
  Connects actin to ECM.
  Stability of myocytes

Excitation Contraction Coupling like sk ms

3 differences

SERCA Sarco-Endoplasmic Reticulum Ca^{++} ATPase.

(1) Contraction Ca^{++} TWO sources

a ECF via L type Ca channels — Sarcolemma, T tubules
small amount

b SR via RyR Ca^{++} channels
LARGE amount
CICR

[2] Relaxation Ca^{++} removal THREE mechanisms

a SR via ATP dependent Ca^{++} pump (SERCA)

b, c] OUT of myocytes via sarcolemma by [ATP dependent Ca^{++} pump; Na^{+}-Ca^{++} exchanger

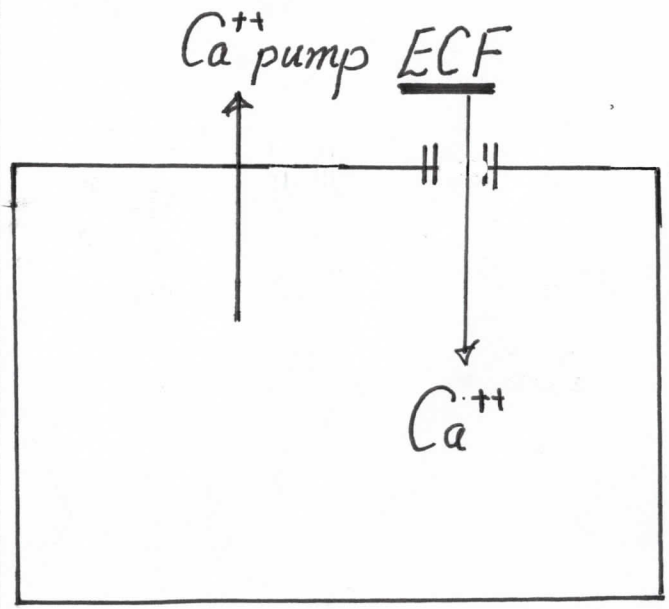
[3] Ca^{++} plays MAIN ROLE in determining force of contraction.

$\uparrow\uparrow Ca^{++} \longrightarrow$ +ve inotropic

15

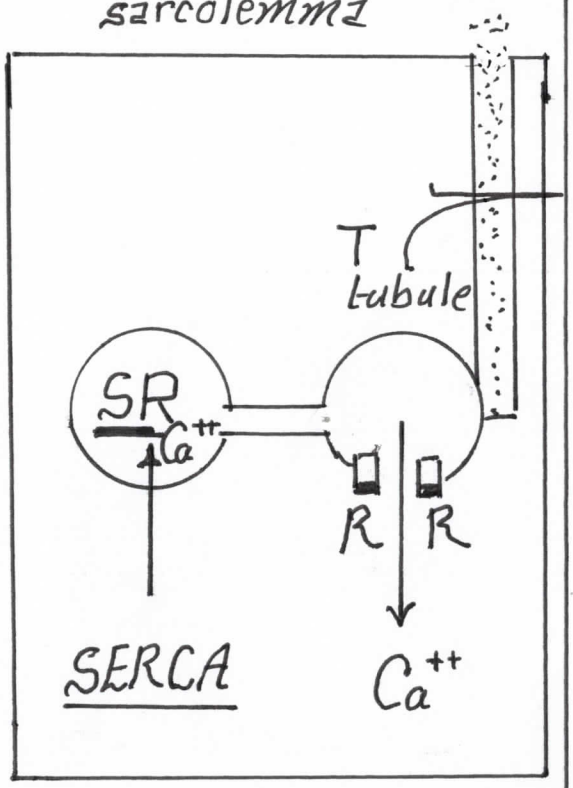
2

Smooth ms (Slow)



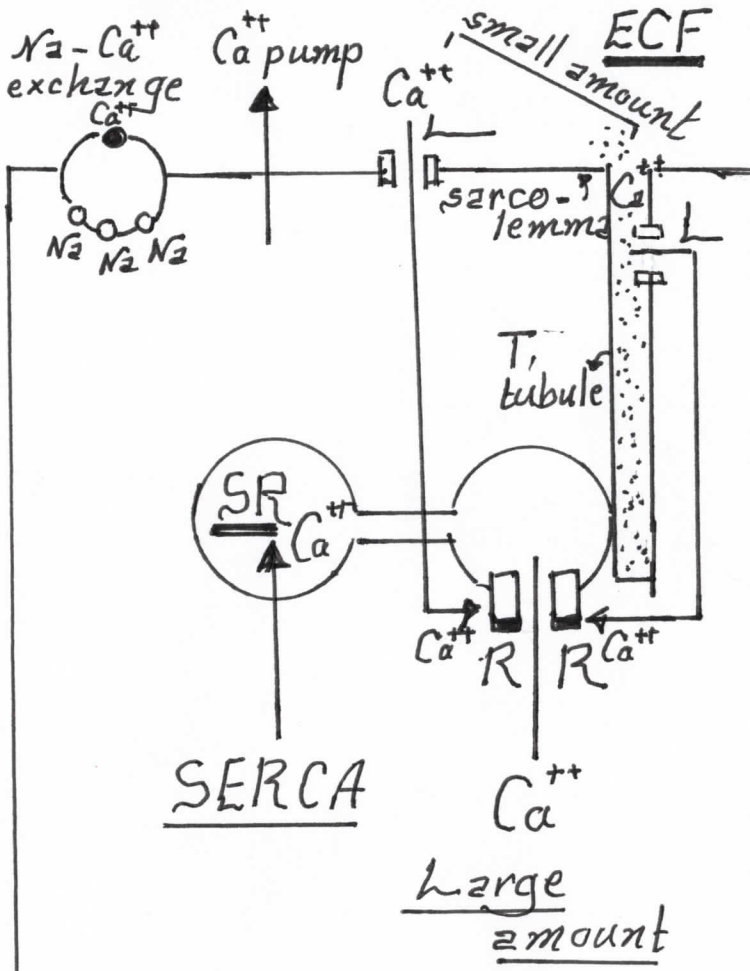
Mainly ECF

Skeletal ms (fast)



SR

Cardiac ms



CICR

ECF & SR (large amo

Regulation of contractility (Inotropic state):

Positive inotropic	Negative
1 β adrenergic receptors ++ cAMP ⟶ ++ Ca^{++}.	1 Muscarinic (M_2) receptors -- cAMP.
2 Glucagon ++ cAMP.	2 Adenosine -- cAMP.
3 ++ Ca^{++} in ECF.	3 Hypoxia -- ATP.
4 Drugs:	4 Drugs:
a Digitalis ⟶ ++ Ca^{++}.	a Ca^{++} channels blockers.
b Xanthine ++ cAMP.	b Anesthetic drugs.

Regulation of relaxation:

(1) β adrenergic receptors

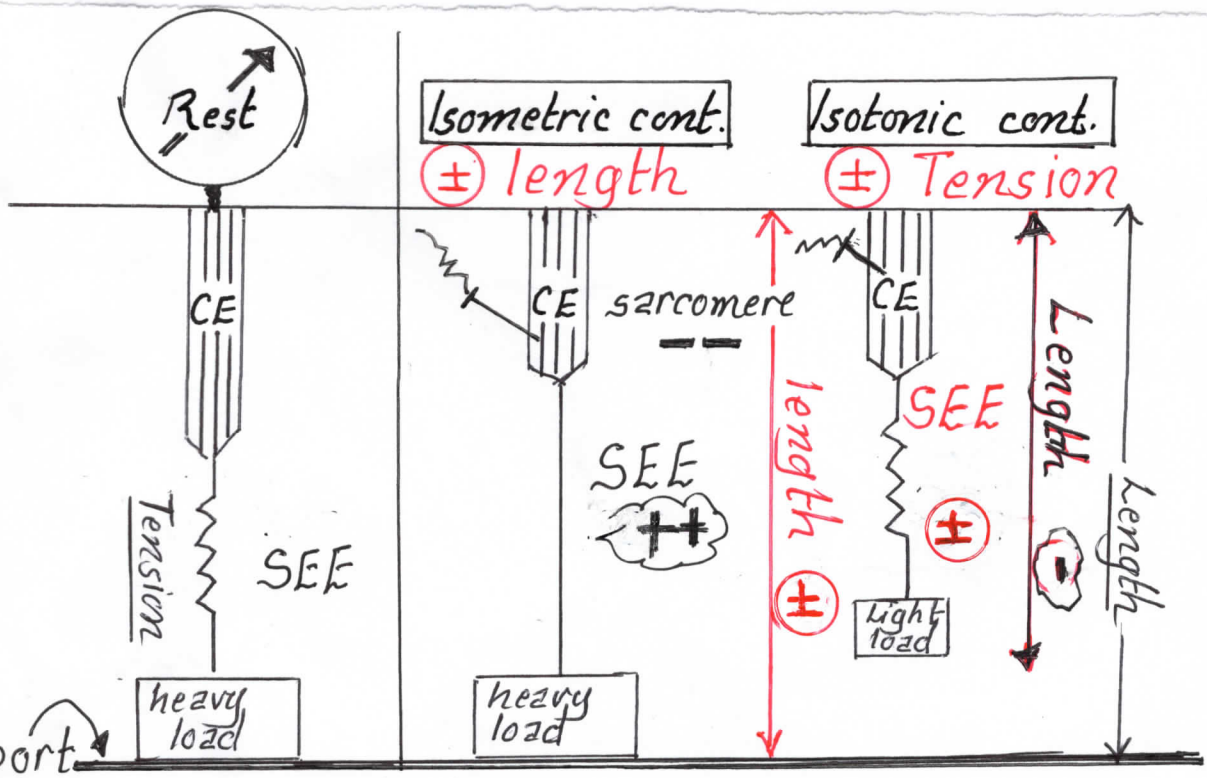
++ cAMP ← activates SERCA pump.

-- binding of troponin C to Ca^{++}.

(2) Myocardial ischemia

++ Ca^{++} ⟶ inhibits relaxation.

Isometric and isotonic contraction of isolated Cardiac ms



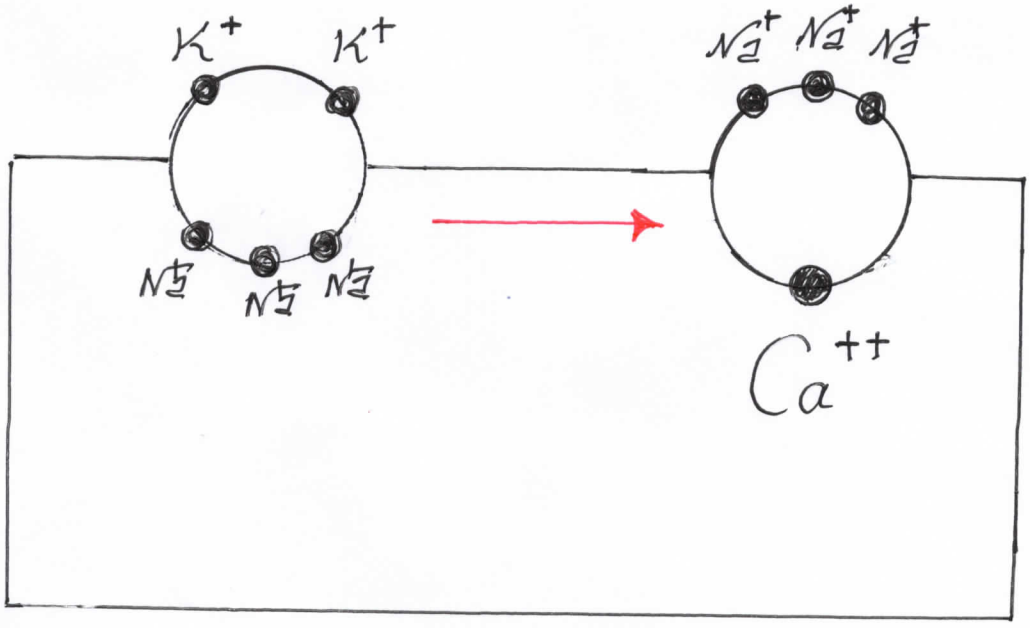
c AMP $\xrightarrow{\text{Activate}}$ ptn kinase A $\longrightarrow$ phosphorylation

- L type Ca^{++} ch. → Open longer time
- Certain site in SR → Release more Ca^{++}

Digitalis

inhibits

modulates



Preload degree of stretch — **Before** muscle contracts

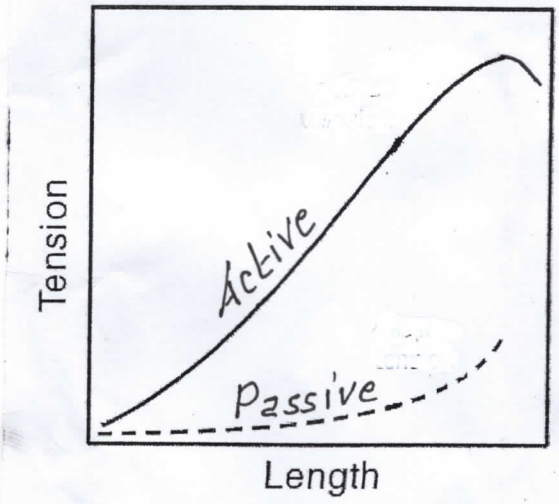
→ **Passive** tension — measures of → Preload

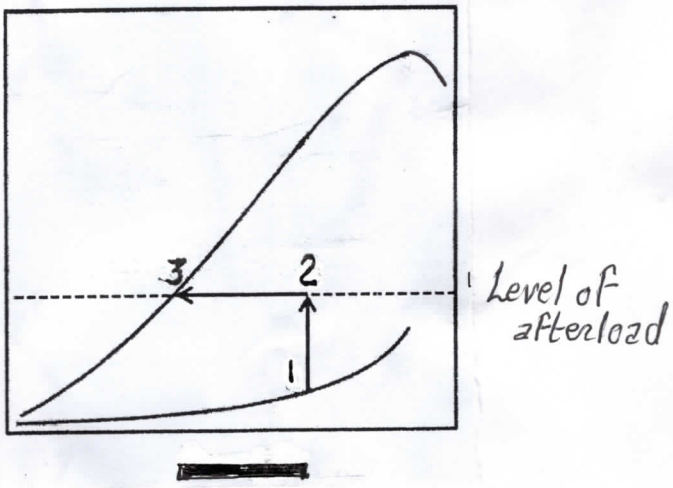
Afterload load against which muscle **contracts**.

→ **Active** tension — measure of → Afterload

Indicators of contraction

Isotonic cont.	Isometric cont
Degree of shortening	Degree of active tension
Velocity of shortening	





Length - Tension relationship

degree of shortening during cont. (represented by line 2-3)

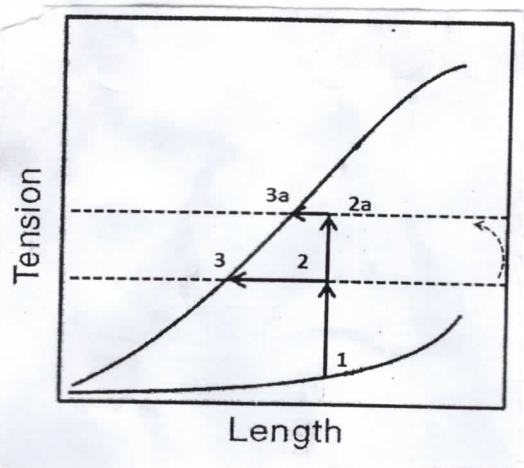
Four major factors affecting performance of isolated C. muscle

1. Preload ++ → ++ within limits
2. Afterload ++ → −−
3. Inotropic state +ve → ++
4. Frequency ++ → ++ then ±

1 Afterload

a Degree of shortening $\propto \frac{1}{\text{Afterload}}$ length tension curve

b Velocity of shortening $\propto \frac{1}{\text{Afterload}}$ load velocity curve



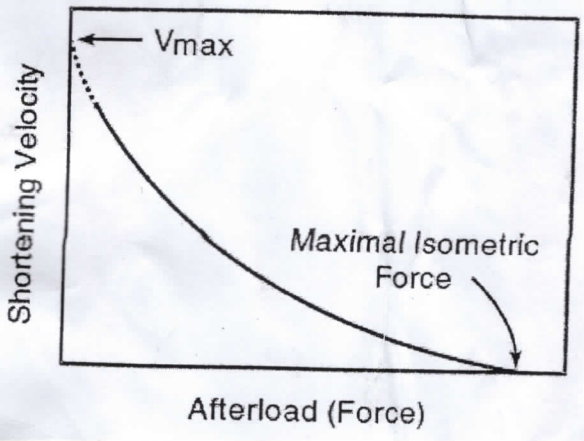
Higher afterload
Level of afterload

1 isometric cont → 2a

2a isotonic cont → 3a

2a Degree of shortening → 3a
Smaller

Effect of increasing afterload on cardiac muscle shortening



Velocity

0 Load ≥ max: tension

V max. Load 0

extrapolated point

Effect of increasing afterload on velocity of shortening of cardiac m

---

2 Preload

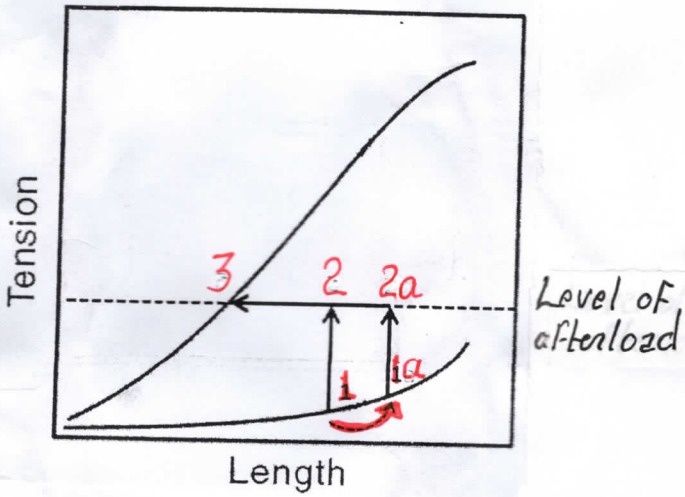
a Degree of shortening ∝ Preload within limit

b Velocity of shortening ∝ Preload within limit

++ preload a ++ velocity curve shifts upwards & to Rt

b V max is not changed.

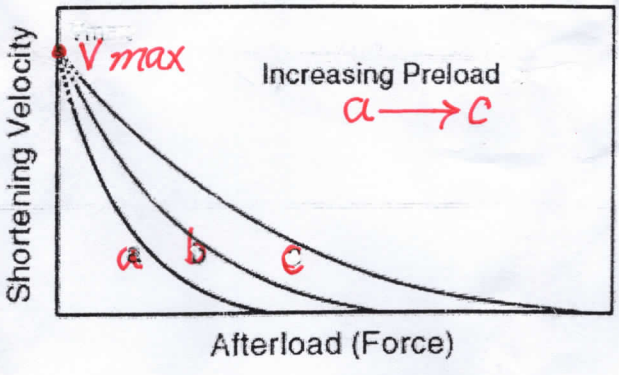
2 Preload



Effect of increasing preload on cardiac ms shortening

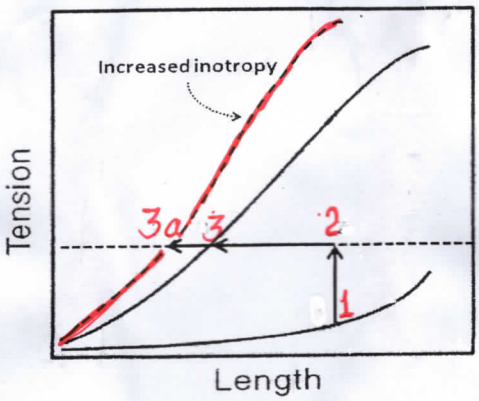
1a — isometric cont → 2a
2a — isotonic cont → 3
2a — degree of shorten. → 3

Greater



Effect of increasing preload on velocity of shortening of cardiac ms. (V max constant)

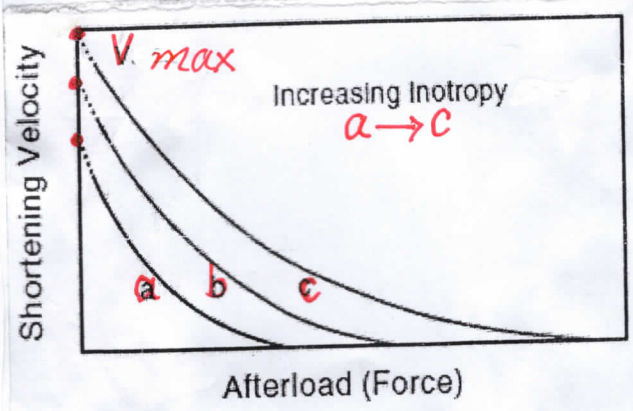
3 +ve Inotropic



Effect of increased inotropy on degree of shortening of cardiac muscle

2 — degree of shorten. → 3a

Greater



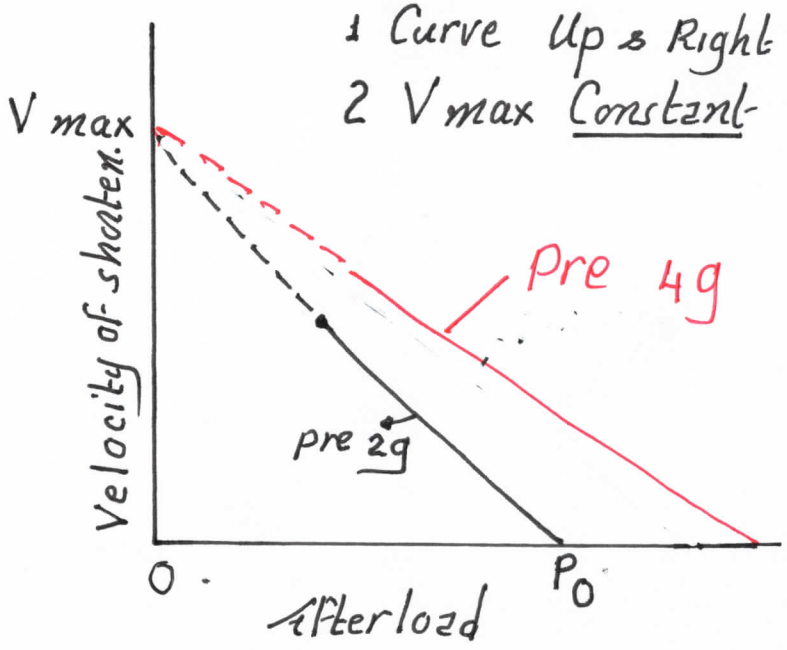
Effect of increased inotropy on velocity of shortening of cardiac ms (Vmax increased)

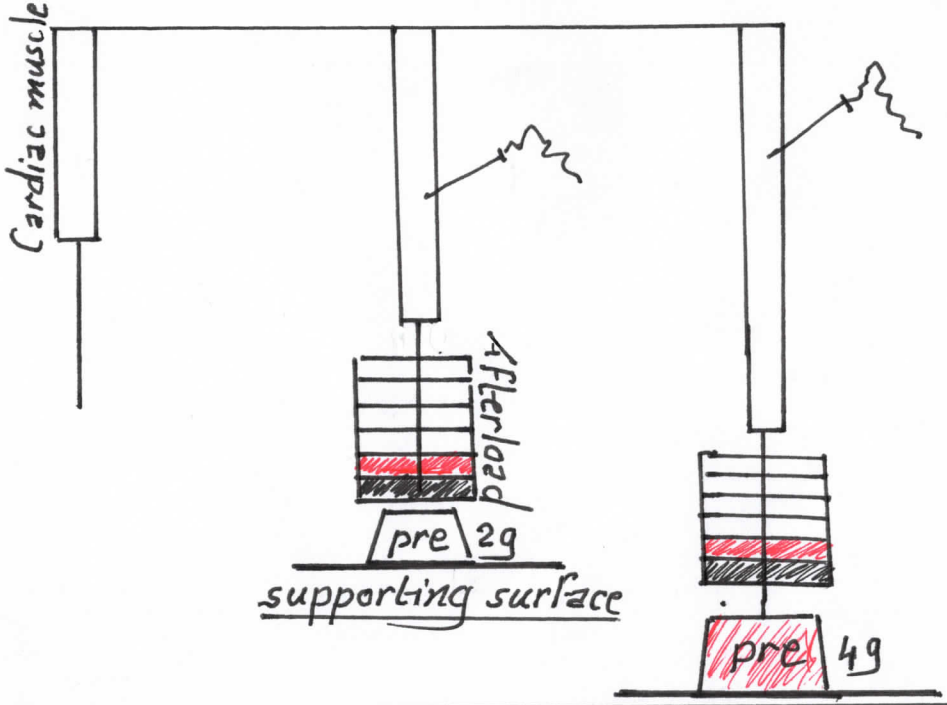
Increased velocity of shortening i.e Curve shifts upwards ↑ to Rt

++ preload

1 Curve Up & Right

2 V max Constant

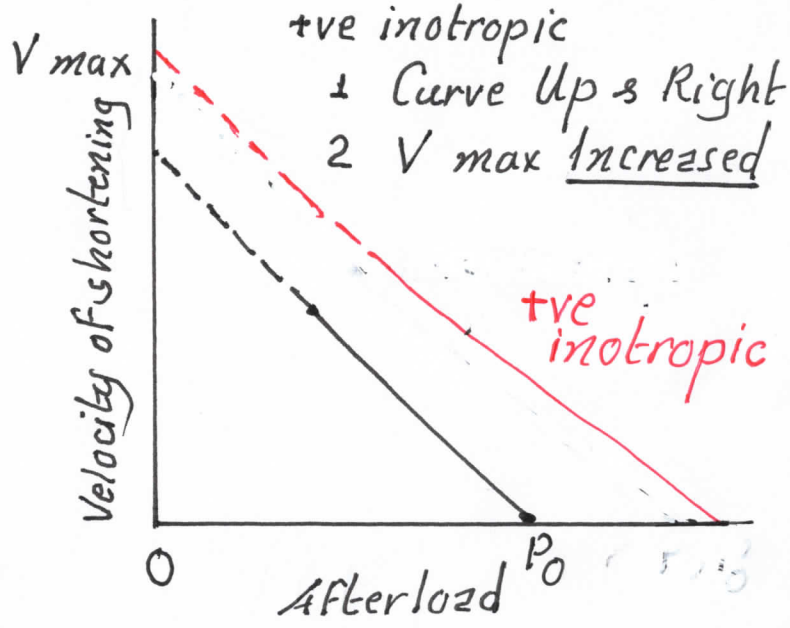


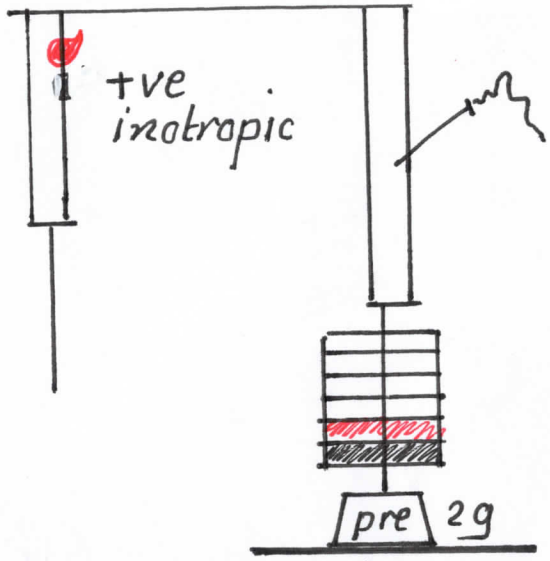


+ve inotropic

1 Curve Up & Right

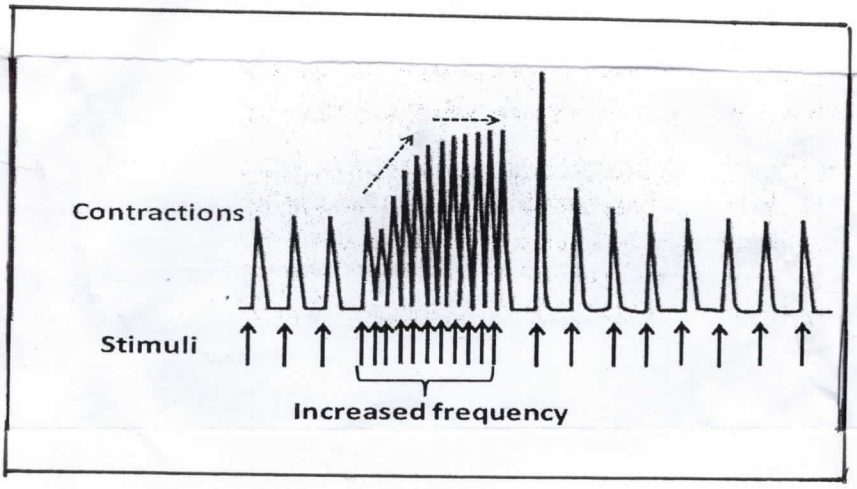
2 V max Increased





4 Frequency

++ Frequency ⟶ gradual ++ in Force
then higher steady state.



Staircase (Treppe) phenomenon.

<u>Cause</u> ++ Ca^{++} concentration.
no enough time for complete removal of
released Ca^{++} ⟶ ++ Ca^{++} conc. in myocytes.