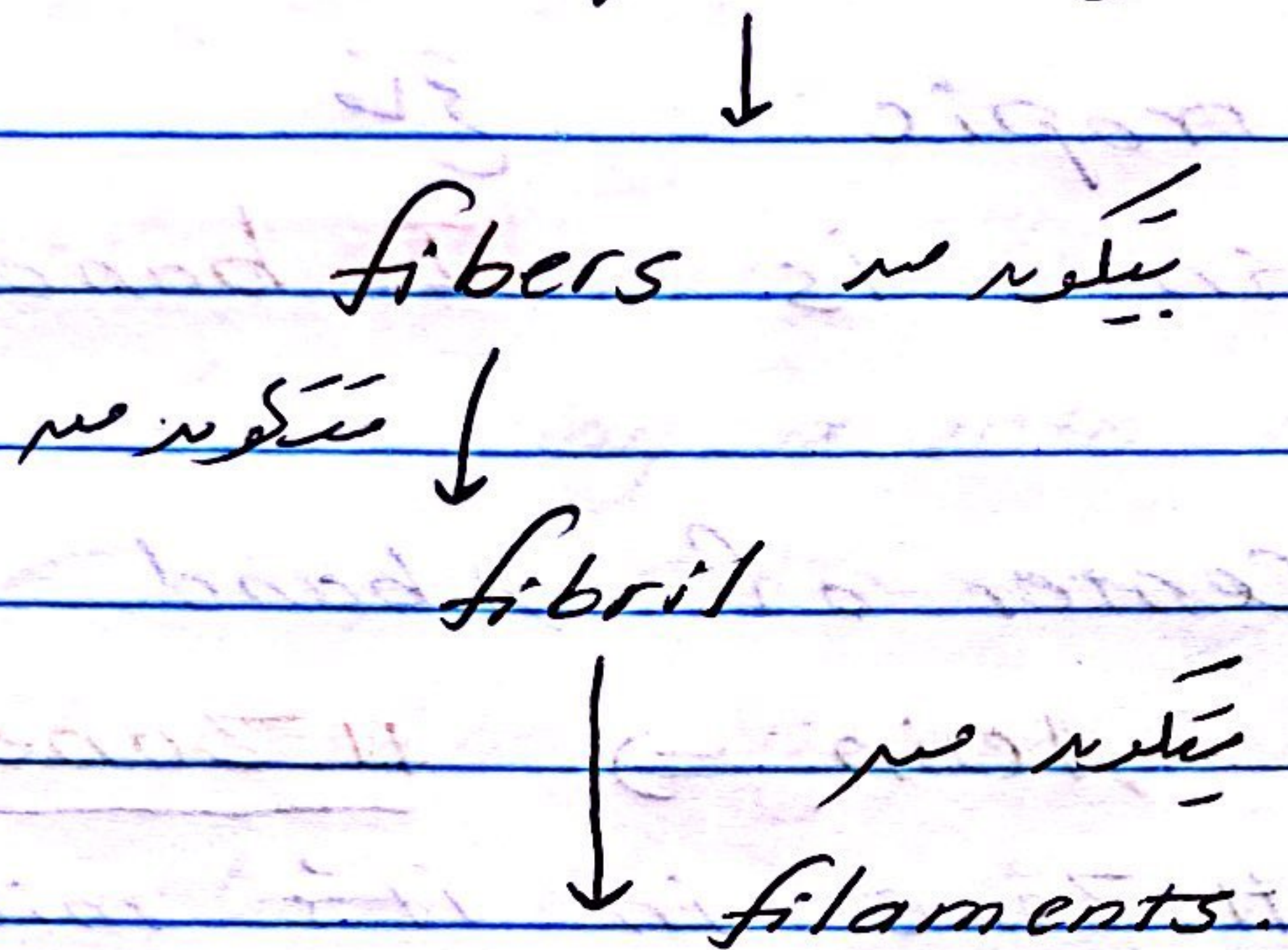


• muscle contain fascicles (Bundle)



fascicle covered by c.T ⇒ called perimysium
 fascicle lined by c.T ⇒ " endomysium
 muscle covered by c.T ⇒ " epimysium

covered
fibers

Connected with
tendons.

myofibril : Thick or Thin filaments

myosin ← Actin ←

myosin = An Isotropic إسوتروبي

So myosin is A-band

Actin = Isotropic إسوتروبي

So Actin is I-band

in the center of A band
there's no Actin $\Rightarrow$ H Zone
and the H Zone in its middle
there's M line.

* Z-line bind to Actin.

* area between 2 Z-lines is Sarcomere

Contraction انقباض $\leftarrow$

Myosins • 6 chains of polypeptides
2 heavy and 4 light chains

• myosin contain 2 heads
one is ATPase site
and one for Actin (Actin binding)
sites

2 heads form a tail

head bind tail by hinge (Joint)

myosin يرتبط بـ Actin

and there's an arm bind with head
and this play a role in contraction

Bare Zone in myosin where the
myosin don't bind to actin

H-Zone. منطقة

Actin :-

Actin has a myosin binding
site

in relaxation state of muscle
the myosin binding site is covered
by **Tropomyosin**

↓
bind to troponin for supporting
(باعتبار تثبيت)

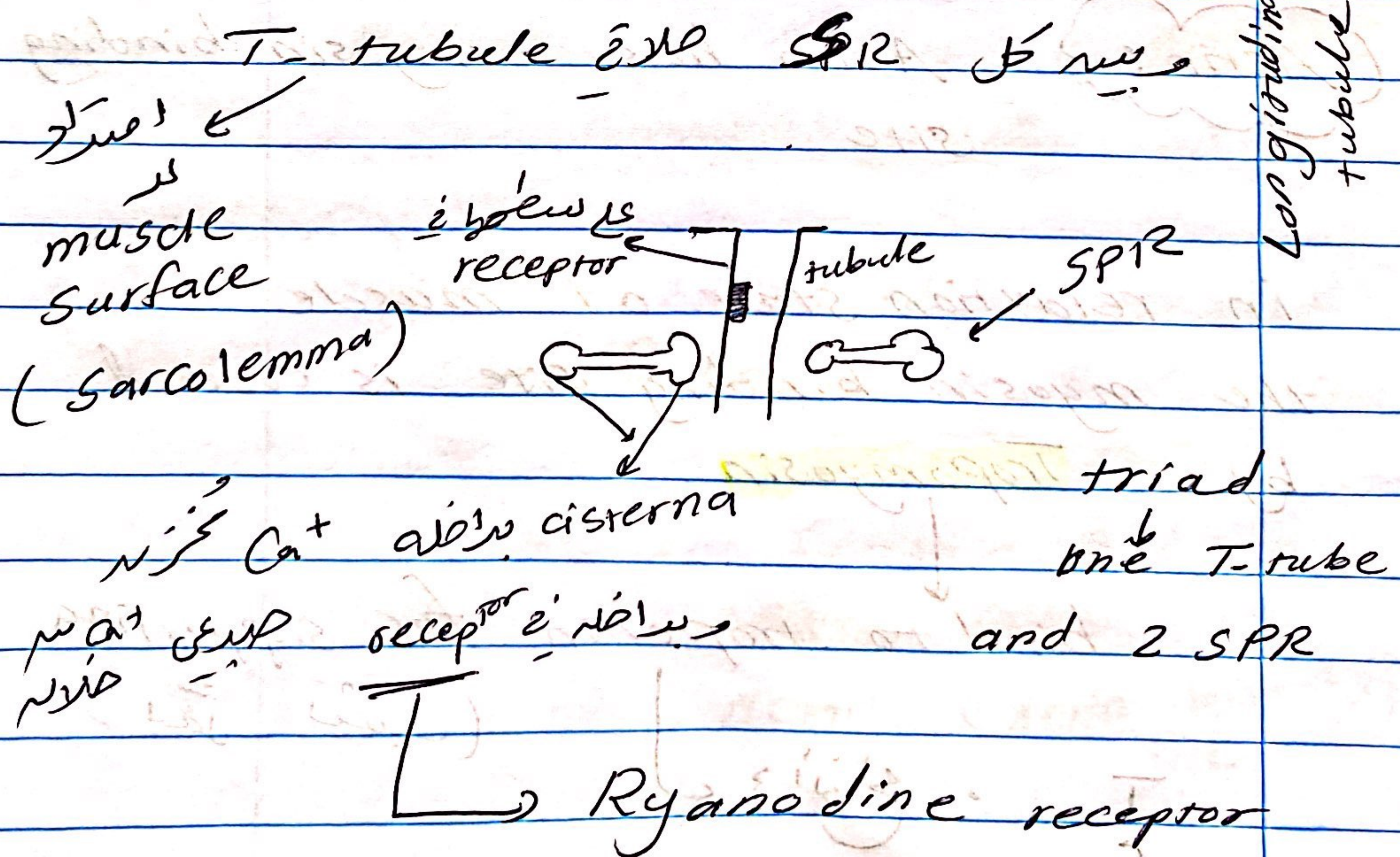
• T
• C
• I

tropoin for fixation

tropoin T bind to tropomyosin
" C " " " Ca^{+}
" I bind to for I band

Along the myofibril there's
a Transverse tubule (فوليكول ليفي)
(T-tubules)

and there's a network of tubules
"Sarcoplasmic reticulum" (SR)



T-tubule receptor is voltage sensor (مستشعر جهد الفعل AP)

Dihydropyridine واسم

"DHP"

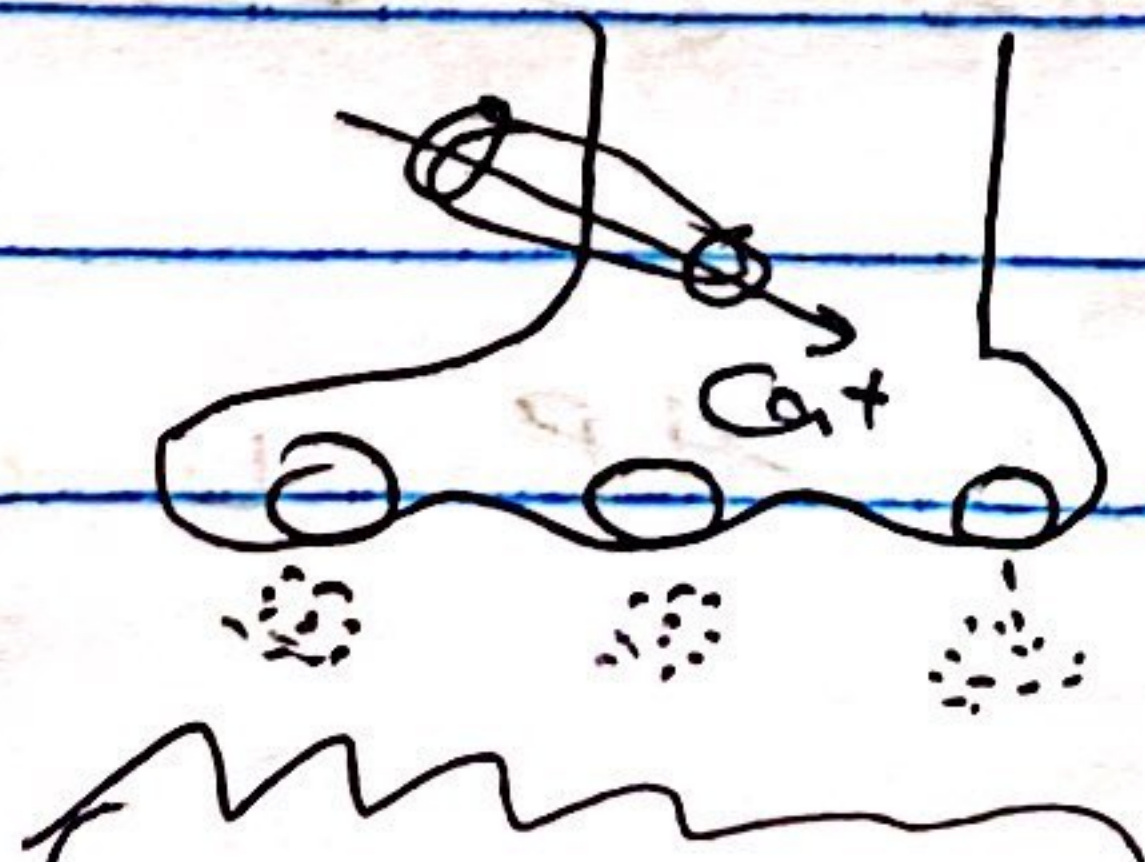
التي تترى عند وقوع SR

Excitation - contraction

coupling :-

Action potential from nerves.

- x Action potential to nerve to open voltage gated Ca^{2+} channel
- x Ca^{2+} from extracellular to nerve (influx)
- x Ca^{2+} bind to vesicles to release Ach.
- x Ach between nerve and muscle



Ach bind to ^{nicotinic} receptor } Miniature EPP
ال و مق يوصل

دخاله في
Voltage gated Na
channel

when bind to Ach

تفتح Na^+ channels
فدا يدخل ال Na^+ ^{صحيح}
local depolarization

و حين هيل ليه

Local depolarization
طرفا توصل Action Potential ويوصله

muscle
طرفا هو عليه ينشر

neuromuscular transmission

muscle Surface "sarcolemma"

A.P ال وصلها و جبي ال T-tubule
و حليله Pass way to A.P
في جبر ال SR
cisterna Ca^{2+} مخزنه

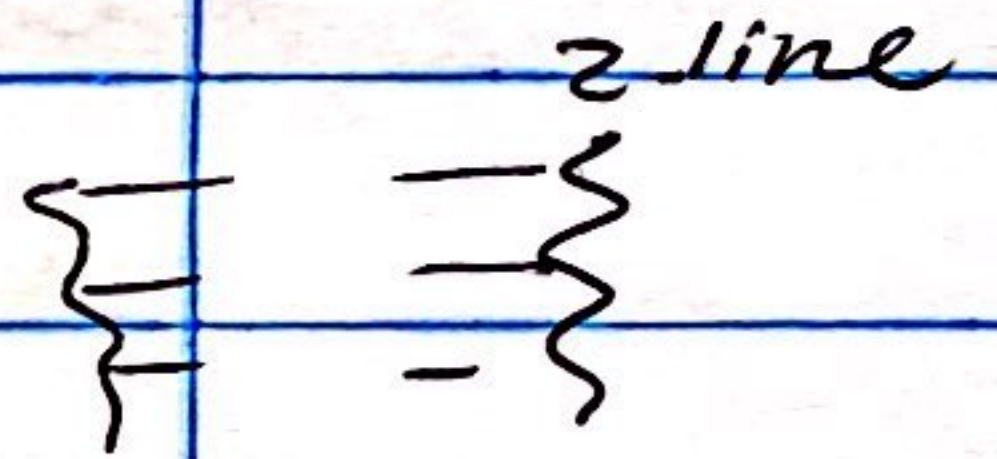
ال و AP يوصل DHP في ال T-tubule

• open and pass voltage to cisterna by foot processes

• Ap reach cisterna $\Rightarrow$ Ca^{2+} bind to Ryanodine receptor and lead to release Ca^{2+}

"Ligand gated" channel.

• Actin bind to Z line and the myosin binding site covered by tropomyosin which is fixed by troponin T



↓
when Ca^{2+} released and reach filament then bind to troponin C
lead to separate tropomyosin and Actin $\Rightarrow$ Uncovered Actin Active site

• cross bridge cycling

myosin has 2 heads and tail
+ Hinge + Arm

head + Arm $\Rightarrow$ called cross bridge

- head bind to Actin $\rightarrow$ [1] Binding
- 2nd h head Bend to bind another Actin $\rightarrow$ [2] Bending

ATP binding site $\rightarrow$ ATP $\rightarrow$ ATP binding site

$\Downarrow$ [3] move the Actin to the center of Sarcomer.

- حقل الطاقة بين 2 زلازل

Called Power-stroke

وهذا حقل الطاقة بين 2 زلازل
Actin $\rightarrow$ myosin

[3] Detachment.

[4] Recycling (عزل مع ATP و Actin)

A-band → لا يتغير
myosin constant (ص. بطول ولا يتغير)
I-band يتغير هو

* Walk-along theory = cross bridge cycling.

[5] Relaxation:

لا يتغير ال Ca^{+} و ال Ca^{+} Conc. في
cisterna muscle ال Ca^{+} في muscle
Filament
مرجع بواسطة (Active transport)
Low to high
by Ca^{+} ATPase pump.

ATP used in Bending
Detachment
Relaxation

لماذا لا يتغير ال Detachment ؟

Rigor Mortis
muscle stiffness
موت
death

Mc ardle phosphorylase deficiency

مرض نادر !!!
↓
تفتقر إلى glycogen . فتش

عسر للطاقة .

Contralure : Contraction ال انقباض

$\uparrow \text{Ca}^{2+}$ release

$\downarrow \text{Ca}^{2+}$ reuptake

Muscle energy

Sources -

in Rest : Fatty acid

in exercise : Glucose

ATP contain Adenine - Ribose - (P)

bind by High energy bond

12,000
Calori

الاحتراق



Ca^{2+} زيادة ATPase enzyme

3 ways for ATP resynthesis:-

[A]

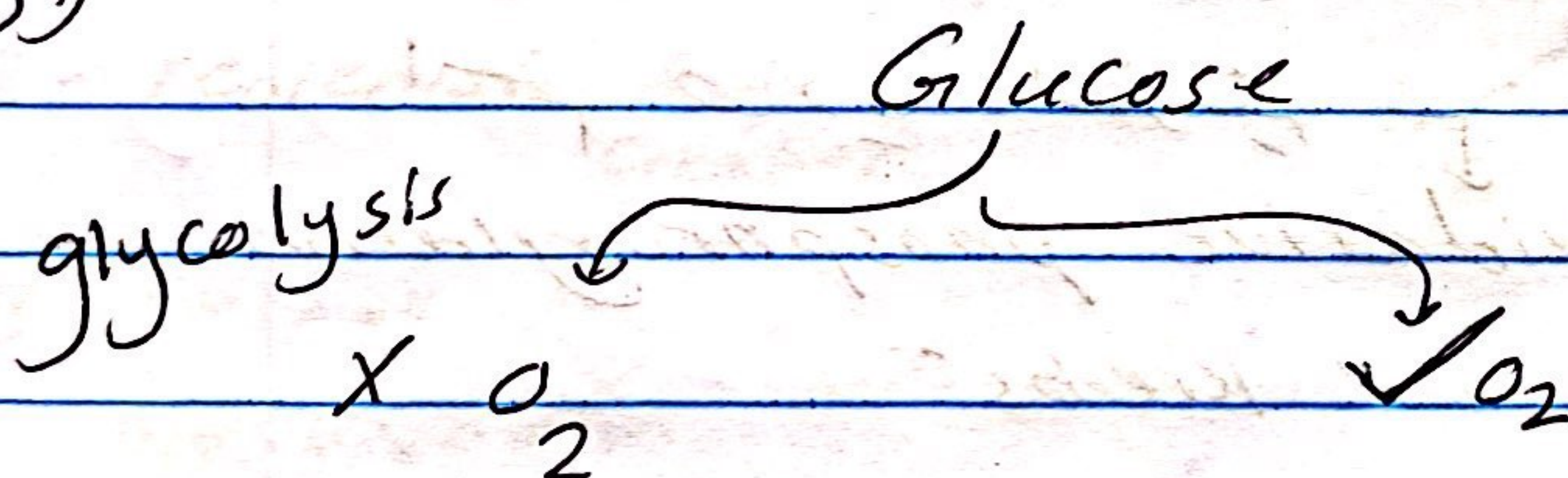
[1] ultra-rapid: creatine phosphate
(5 sec)
creatine + ATP $\xleftarrow{+ADP}$

لوقت قصير جداً

• High intensity and short duration.

[2] Glucose from blood

glycogen break down
بالعضلات
مخزن



Exercise

عند البداية
Anaerobic

↓
Aerobic

↓
Anaerobic

Glucose + 2 ATP

↓ anaerobic

4 ATP + lactic acid

2 ATP
لوقت قصيرة جداً

تسبب
muscle cramp
or fatigue

لوقت طويلة جداً

aerobic
أو لوقت طويلة جداً

muscle
Contraction lead to compress blood
vessel. $\Rightarrow$ Anaerobic

Aerobic: O_2 from Hgb to muscle
or from myoglobin
(inside muscle)



بإرضاء الخلية في ميتوكوندريا وأثناء بيدي أفضل ال
Pyruvic acid $\xrightarrow{\text{steps}}$ Acetyl CoA $\rightarrow$ ATP

اسم هادي الطريقة
Oxidative phosphorylation
"Krebs"

glucose + O_2 + 2 ATP

$\downarrow$
 $6O_2 + 6CO_2 + 40 ATP$

استغرق 38
ATP

used for long duration exercise.

السهرية

O_2 debt : extra O_2 paid to lung during recovery period after exercise.

to restore the normal metabolic activity.

types

O_2 debt 1 → small O_2
Short duration exercise

مستندة في

Anerobic في

Lactic acid كيميائي

في الأنزيمية بكتيريا خلية أو

موسم لونه السجود خلية

خا

- 1- Oxidative enzyme
- 2- replenish ATP
Creatine P
- 3. Storage in
myoglobin.

A lactic acid

from 2 to 3 min

2

Lactic type 1 hour

Long duration

↑ Lactic

صيقول

Pyruvic
acid

Krebs

38 ATP

break
down in
liver

storage as
glycogen in
muscles.

muscle fatigue

↓ temporary decrease in the density of contraction during exercise

- back to normal level at rest.

Causes :

- (i) ↑ lactic acid
(by inhibition of key enzymes in mitochondria)
- (inhibition of glycogen)

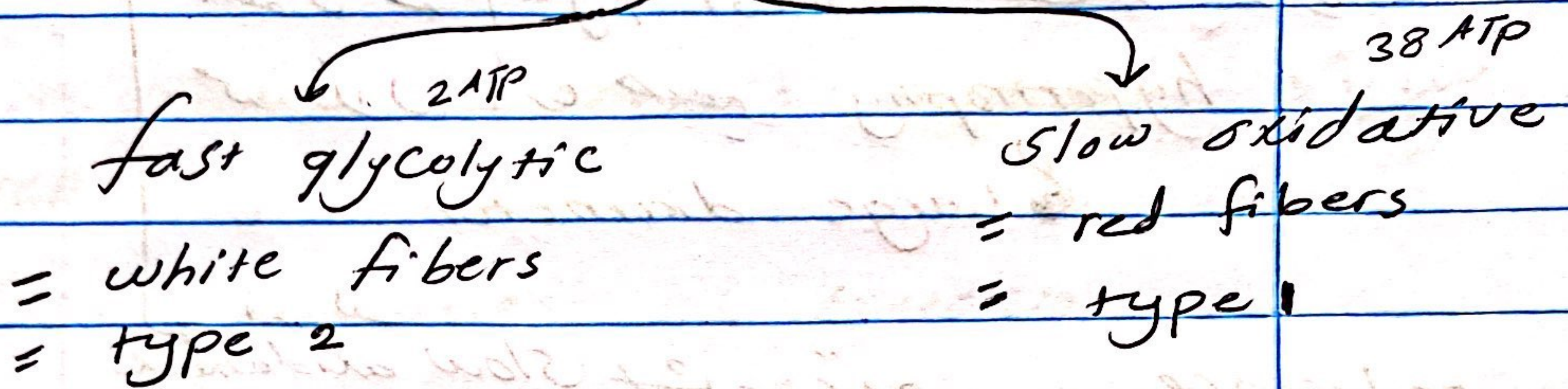
2) neuromuscular fatigue
Depletion of Ach vesicles

[3] Psychological fatigue

onset? • type of exercise (heavy exercise)
(short duration)

• type of muscle fibers
(نوع، حجم، کثرت، و دفع لا تحمل مجہود کثیر)
(adaption of muscle) + اس:

muscle fibers



	fast glyco	slow oxidative
suited for	Heavy exercise	Long aerobic exercise
	Short duration	endurance

source of energy	Glycogen	Aerobic "krebs" cycle
------------------	----------	-----------------------

Capillaries	Low	high
nu. of mitochondria	Low	high

speed of contraction	fast	Low
intensity	High	Low
cross bridge cycle	fast	slow
myosin ATPase	fast	Slow
fatigue	rapid	resistant
endurance	X	✓
site	upper limb	lower limb

• Adaptation training

أصل للعضلات fast glycolytic لعضلة أقوى

من حيث أنه كبير hypertrophy

↳ Large diameter

endurance Slow oxidative

• type 3 of muscle fibers

↓ rare :-

(البطيء) fast oxidative (type 1b)

mechanical efficiency:-

$$\frac{\text{work done}}{\text{energy expenditure}} \times 100\%$$

25% work
75% waste heat

↳ viscosity

يقلل الاحتكاك بين

Actin, myosin
من أجل contraction

Types of Contraction

contractile element $\rightarrow$ myosin + Actin مبصرًا =

elastic element $\rightarrow$ tendon

= elastic series (SE)

صصلة مع السوائى

Actin + myosin

contraction
 $\downarrow$ Contractile element
 و ستر ال tendon

tendon
 Actin myosi

و كسك ال tendon

عضو الساق ال فقرة و هو
 اسره
 Iso metric contraction

الم شانه
 نواجم
 gravity =

constant muscle length
 $\uparrow$ muscle tension (tendon) (stretch mechanical)

work = 0 = Zero
 $\downarrow$
 force distance

Mechanical efficiency zero

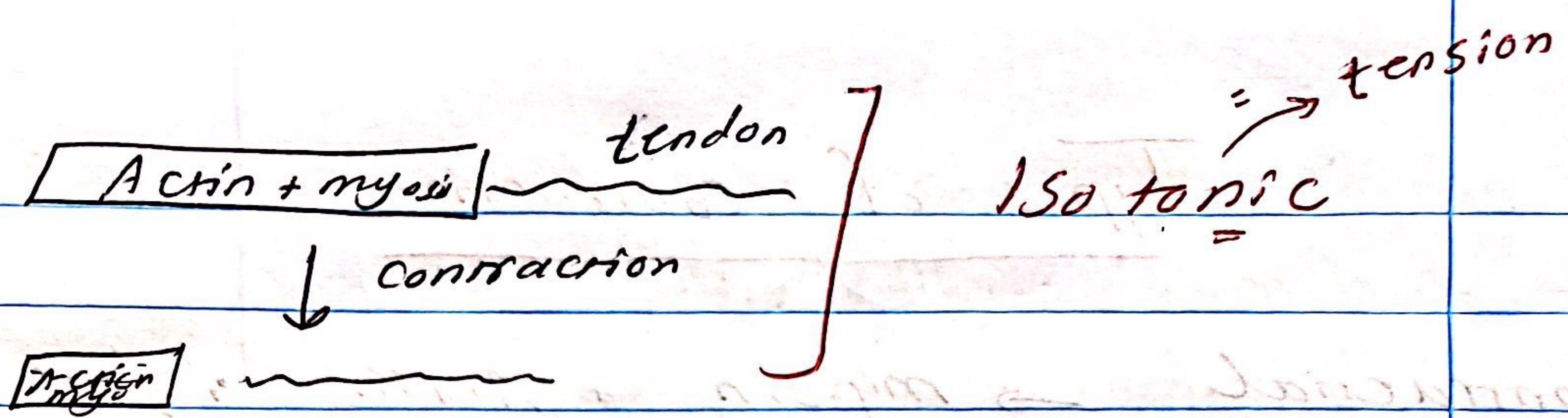
Time $\Rightarrow$ less

energy $\Rightarrow$ less

(على انقباض)
 I ك

Maintain Posture / احمية

مصور
 درجته



muscle length ↓
Tension Constant

work 25% (عند 1.75 ج 1.75)

mechanical efficiency 25%

(مقاومة بطول أو
زمن) Time more
energy more

Isotonic 2 types { concentric
eccentric

التعب
(يبدأ مثل
التمرين) Gradation of skeletal
muscle contraction :-

single muscle fiber not grading
it's obey All or Non Low
(whole muscle fibers)

motor units

efferent nerve (motor neuron)



Supply group of muscle fibers

So: motor unit = 1 nerve + group of muscle fibers.

لوحه آلتر من nerve و يمدو Supply الحركات
منه الى muscle fiber
↓
neuronal pool

Recruitment: ↑ the number of motor unit

gradtion of contraction و يزداد

بالذات من 30 الى 100 fiber
منه الى contraction و يزداد recruitment
الى 30 من 70

Peak of contraction increase

كبير
Large adjustment : Coarse adjustment
motor unit. وحدة كبيرة

Small motor : fine adjustment
units

في وحدات صغيرة
fiber 6-3 وحدة

Coarse عدد
fibers كبيرة 160 - 120
Large motor unit -

motor unit : Slow or fast

in back
leg
fatigue resistant

in Gross
Actions

are recruited in
Long duration
exercise

Degree of muscle
stretch :-

↑ muscle length = (↑ stretch) **Starling Low**

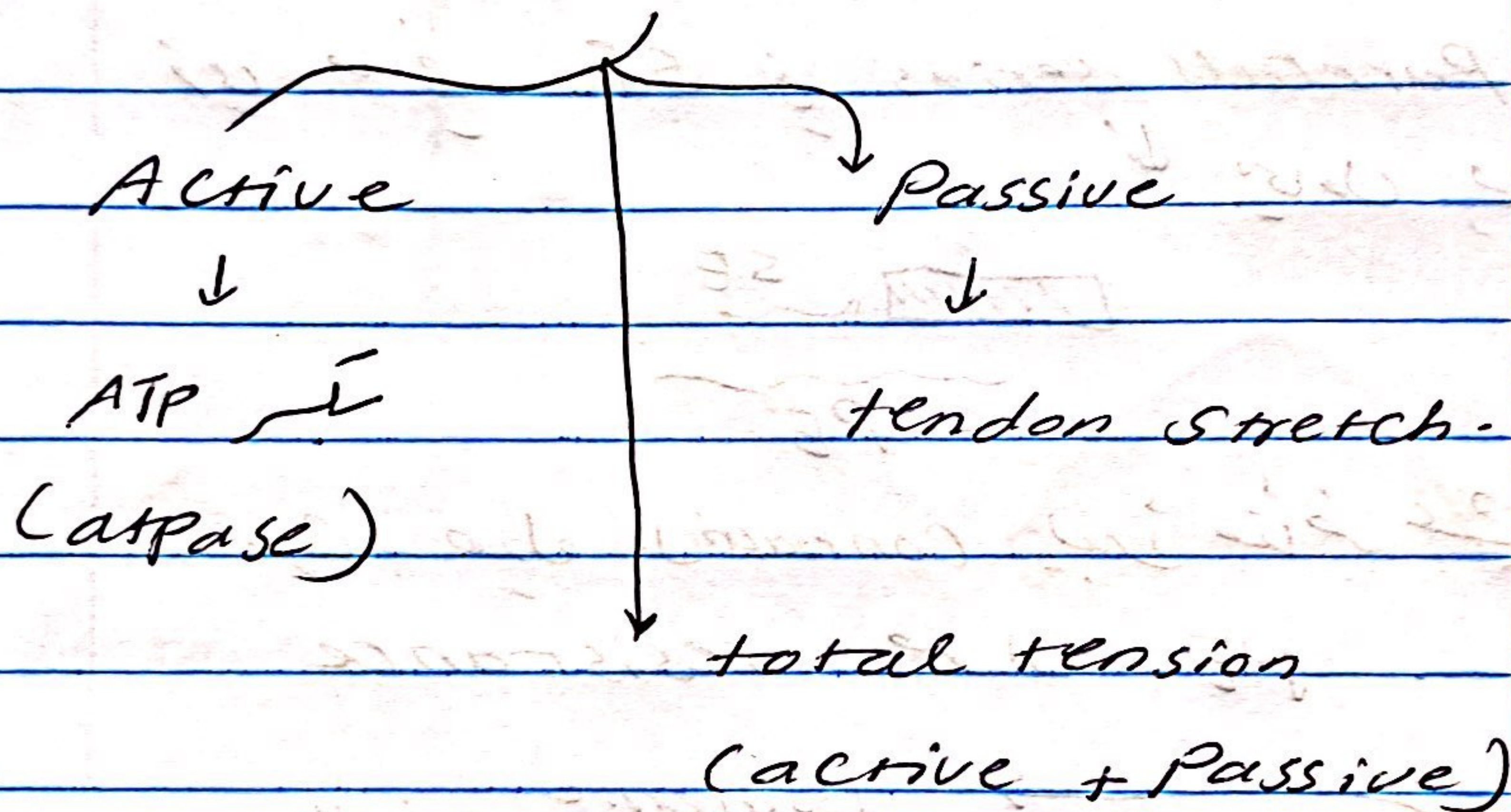
↓
↑ the force of contraction

Starling law : increase muscle length lead to increase force of contraction

لبعض الـ Actin
والموسين myosin

"within limit"

Tension (قوة الانقباض)

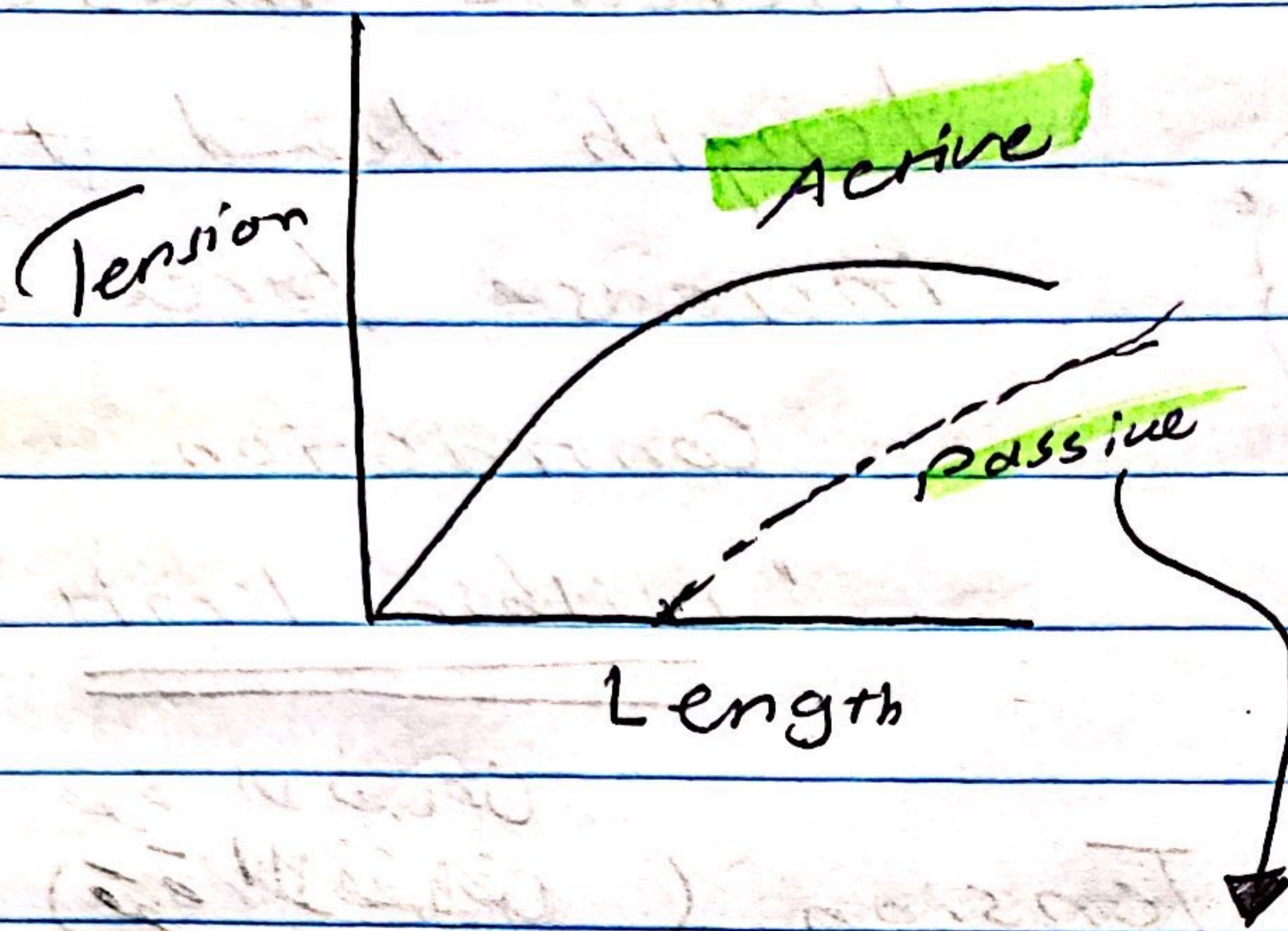


Isometric contraction → stretch
↓
Gravity (stimulant) → lead to ↑ force of contraction

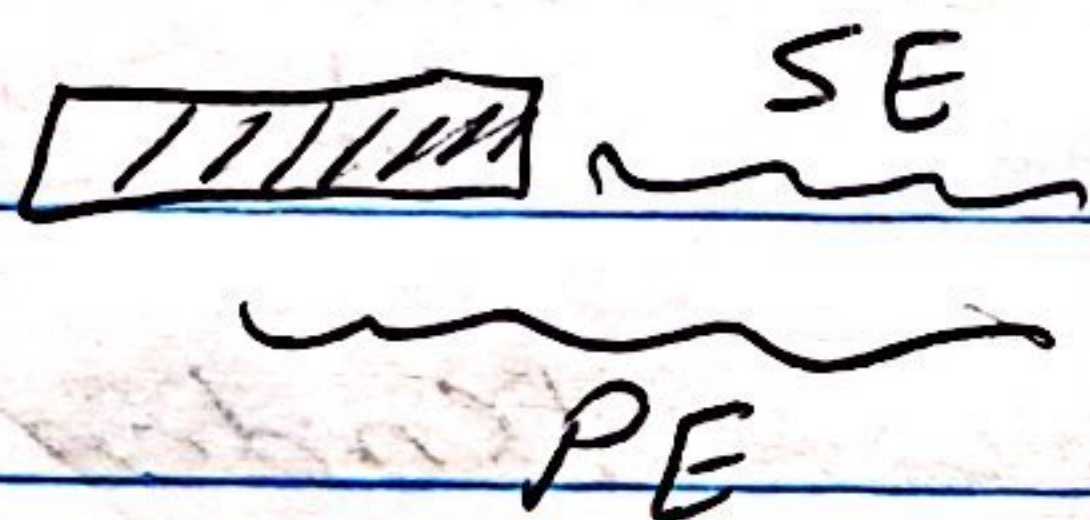
stretch tendon

↓
↑ stretch

↑ length. ↑ contraction.



(PE) Parallel series & SE & si
 ↓
 strength

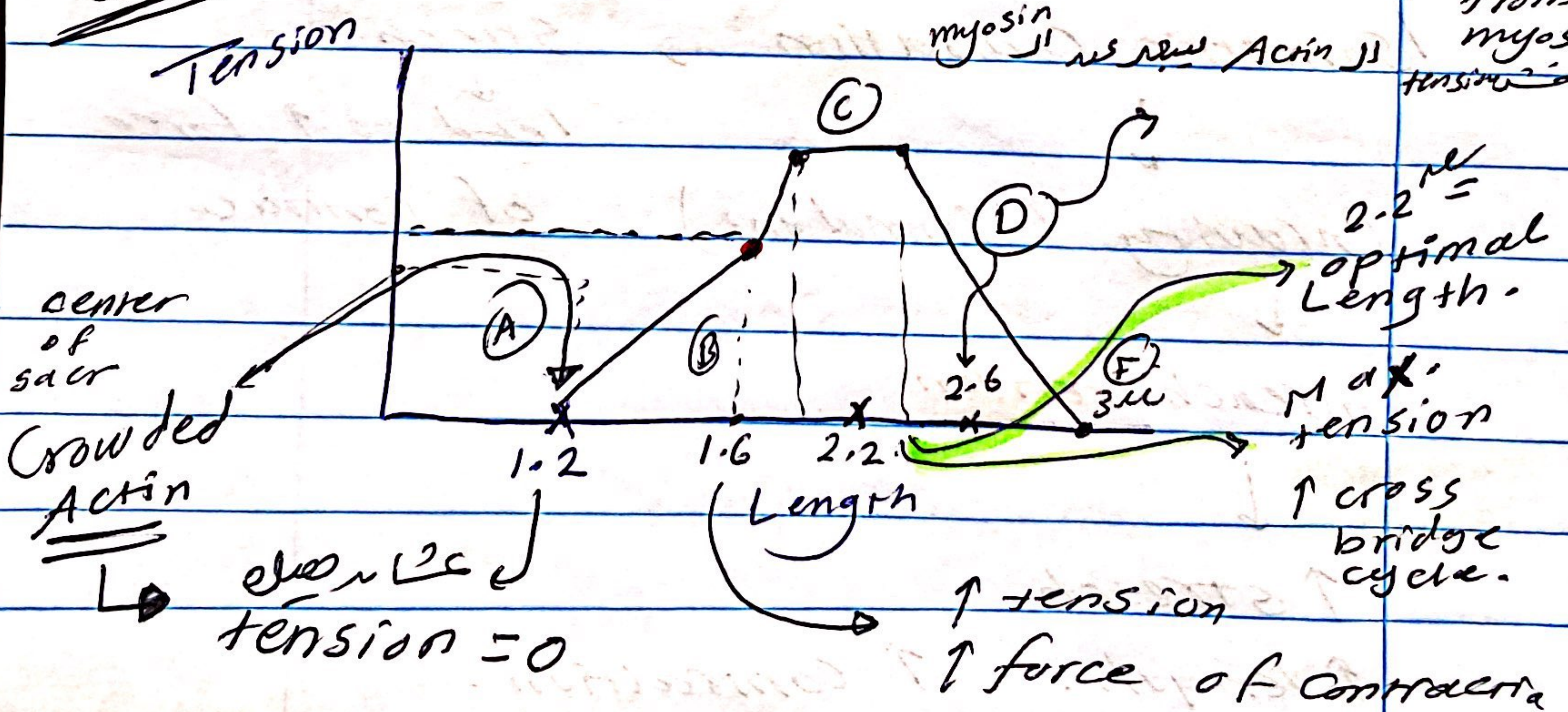


Contractile unit
 PE resistance

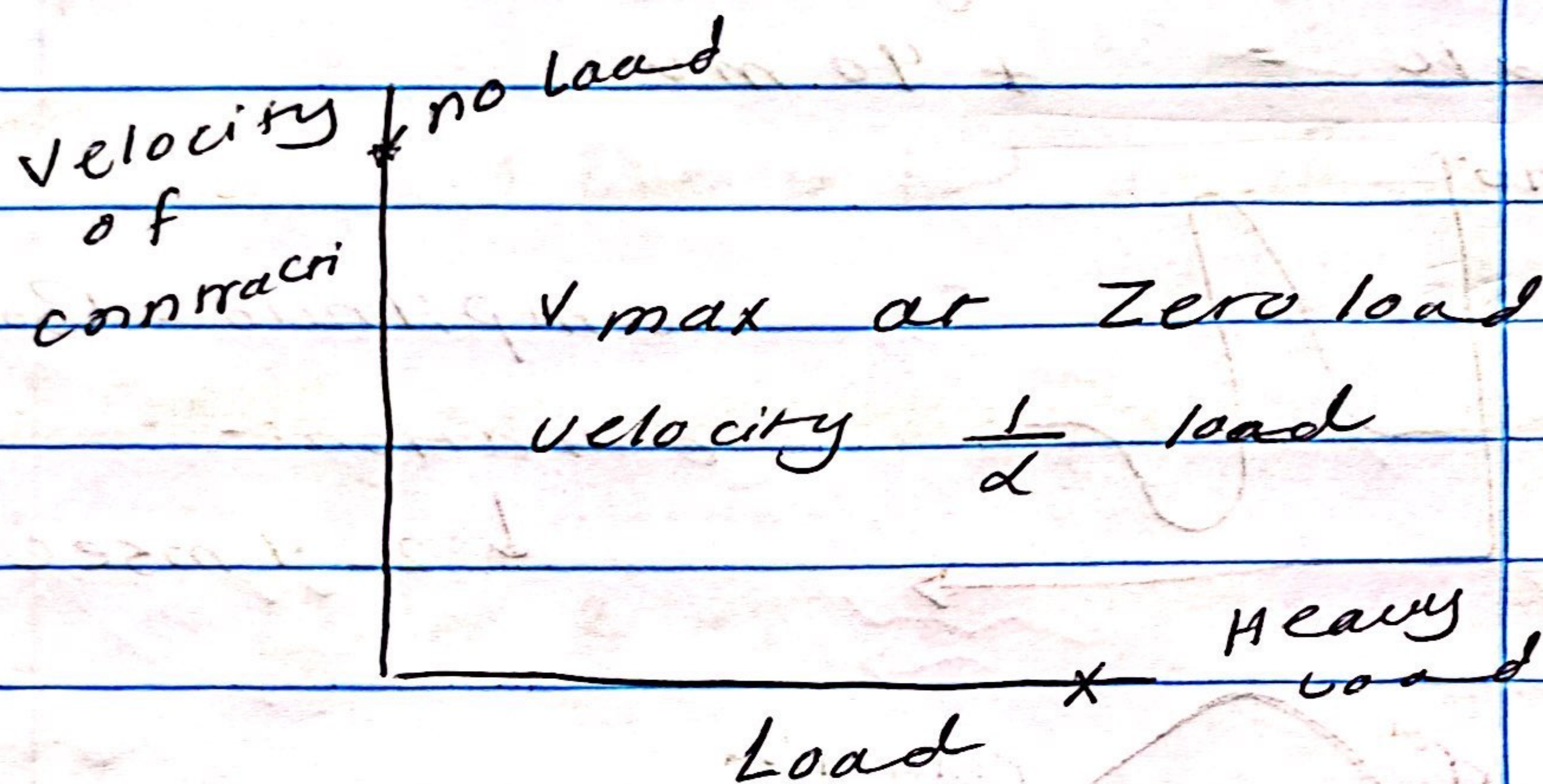
Within Limit

Isometric
length - Tension relationship

(F) Actin pulled from myosin tension



Optimal length $dt = 2.2 M$
 $\Rightarrow (L_{max})$ or preload.



after load : انسان contraction
Isotonic و انقباض في

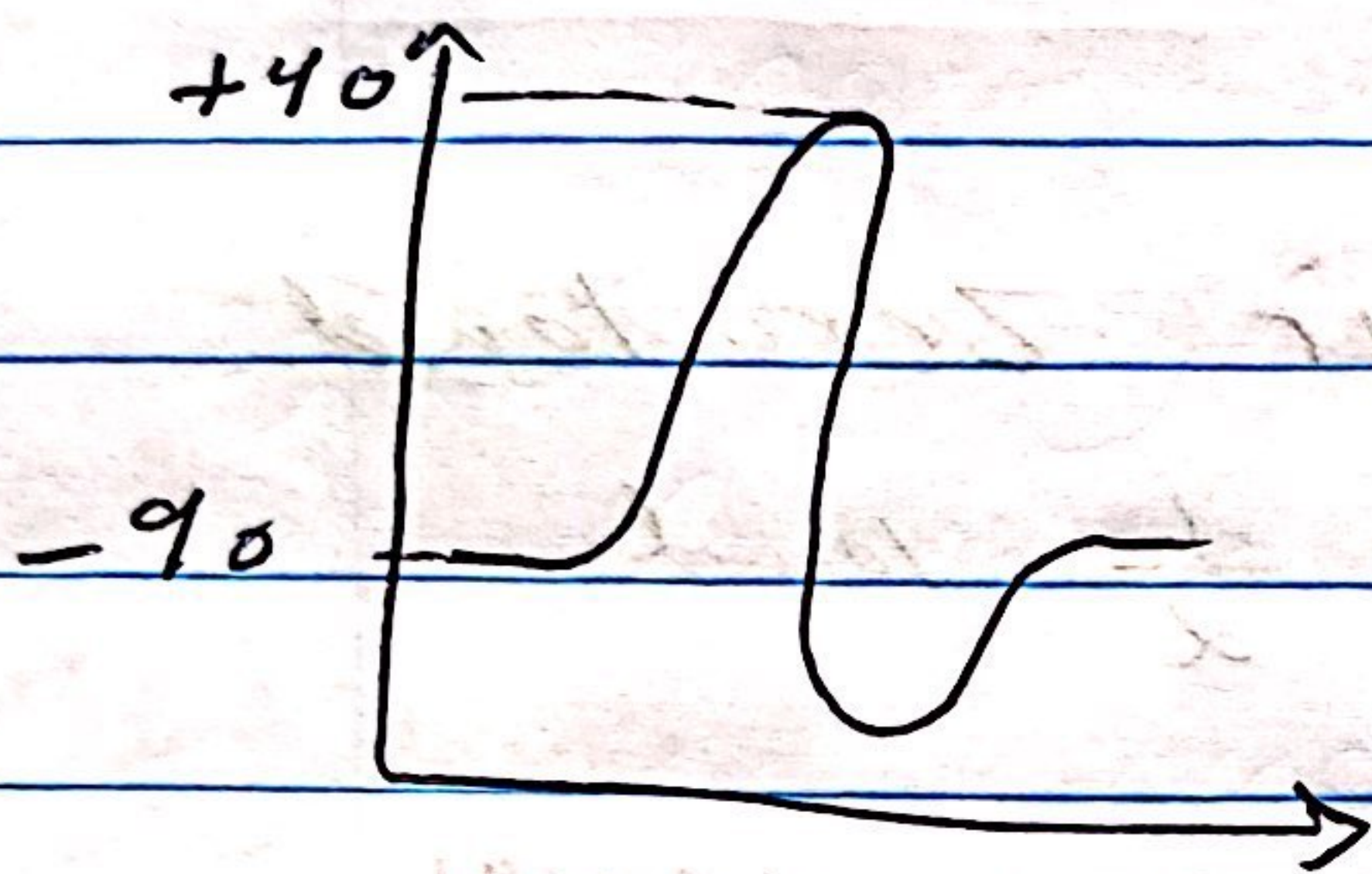
So Isometric depends on Preload
Isotonic " " afterload

muscle Action potential:

RMP = -90 mV

firing level = -40 mV

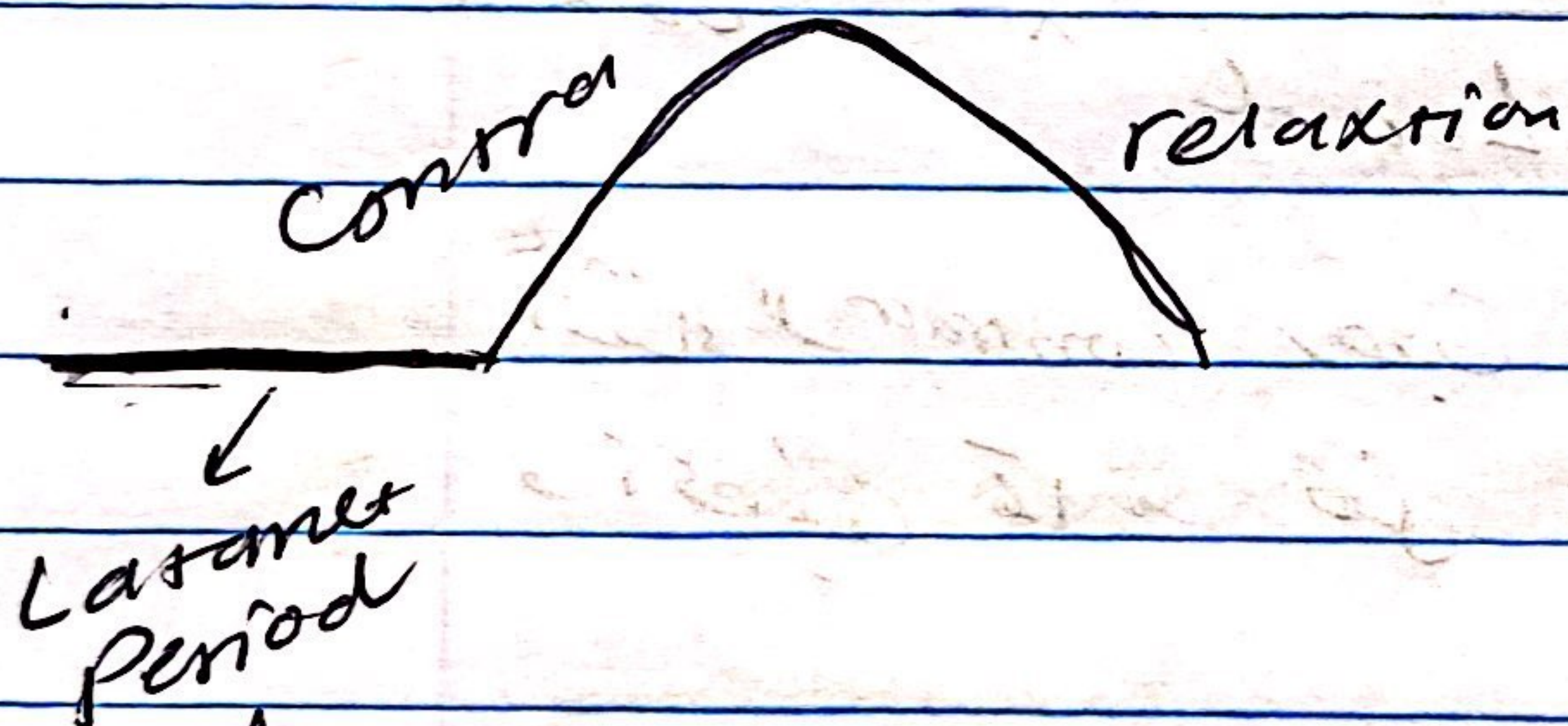
Peak = $+40$ mV



amplitude = 130 mV

duration:-

↓ $2 - 4$ msec



- 1) to open nerve gated voltage
- 2) release of Ach
- 3) Ach bind to receptor
- 4) mechanical response by Ca^{+} release → cross bridge

ARP

ترالسع

Absolut refractory period → Laten period

في nerve وقت ال

depolarization + 1st $\frac{1}{3}$ of repolarization

response → الفترة! لا للربا لا muscle لا response

ARP Relative refractory period → contraction

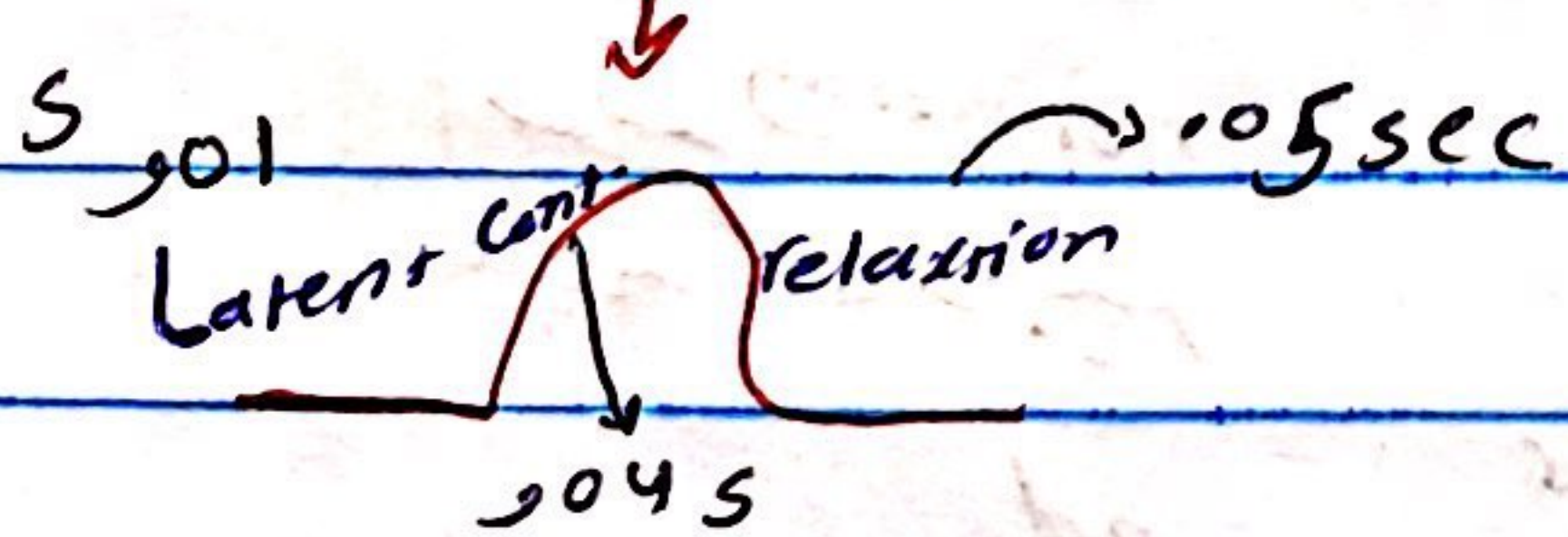
Lower $\frac{2}{3}$ of repolarization

كأن بعد ARP

So mechanical response can be Summated.

frequency of stimulation

شعاع موجوده
بالرأسه
single double multiple



one contraction

followed by one relaxation.

Called : Simple muscle twitch.

Simple muscle (SMT) in twitch

Factors that affect contraction:

- 1) type of muscle fiber (fast & slow)

Latent period
contraction
relaxation

القاس

- 2) Starling Law

- 3) fatigue (caused by repetitive stimuli)

- 4) temperature (duration ↓) by ↑ enzymatic reaction
warm → (amplitude ↑) ↓ viscosity
cold → [↓ amplitude, ↑ duration]

- 5) Successive Stimuli

(A) 1st stimulus → contraction → relaxation

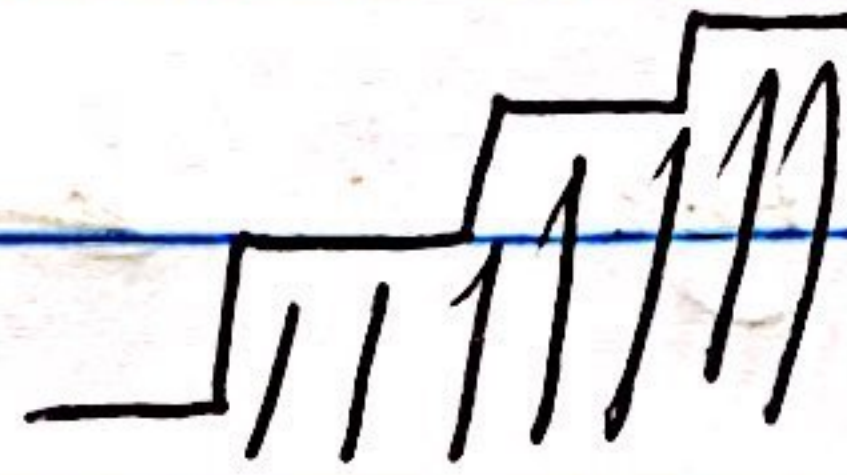
contraction
relaxation
fused contraction
2nd contraction

(B) 2nd stimulus → contraction → relaxation
"Tetanus"
normally

(C) 2nd stimulus → relaxation → contraction
clonus
incomplete relaxation
normally

Stair-Case phenomenon: (Treppe)

- ↑ frequency of Action potential
- ↑ Ca^{2+} release from cisterna
- ↑ Contraction



- ↑ force of contraction

muscle diseases

- * cramp: ↑ lactic acid or abnormal electrolyte (K^+)
↓ blood flow

- Tetany: A.P. ↑
↑ Contraction ← ↑ Ca^{2+} release

↑ Ca^{2+} release
from sarcoplasmic
reticulum

hypocalcemic tetany

[3] muscle atrophy: انحسار

damage the efferent nerve
that supply muscle

↓
stop the

atrophy ← muscle action

↓
Paralysis → (fasciculation
fibrillation)

rupture انقطاع all كل Ach في muscle

contract تقلص muscle في muscle

fasciculation
contraction

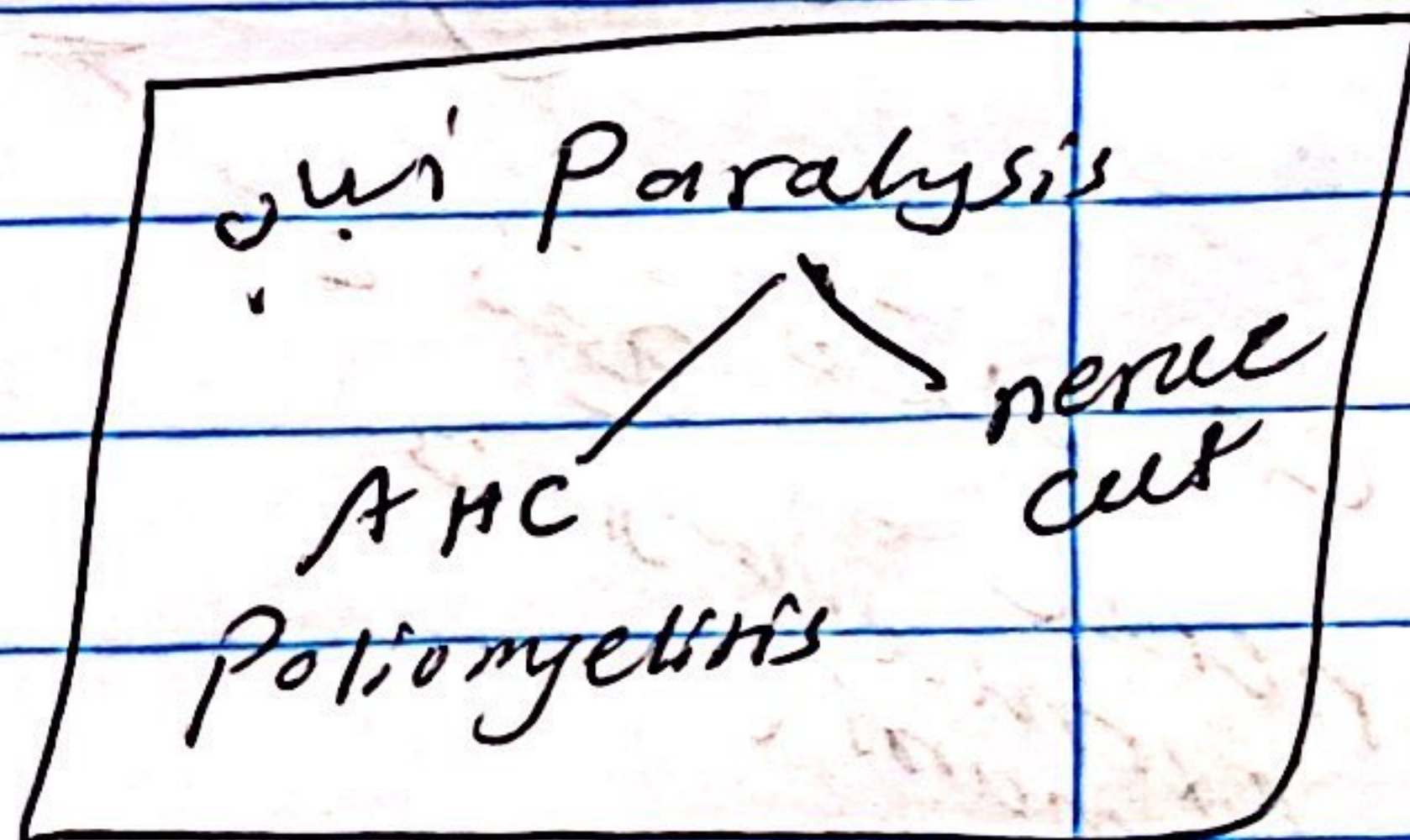
> fibrillation
contraction

↓
يشعر به ويبدو

(felt and seen)

↓ felt only.

+ dystonia



electromyograph جهاز تسجيل العضلات

The end