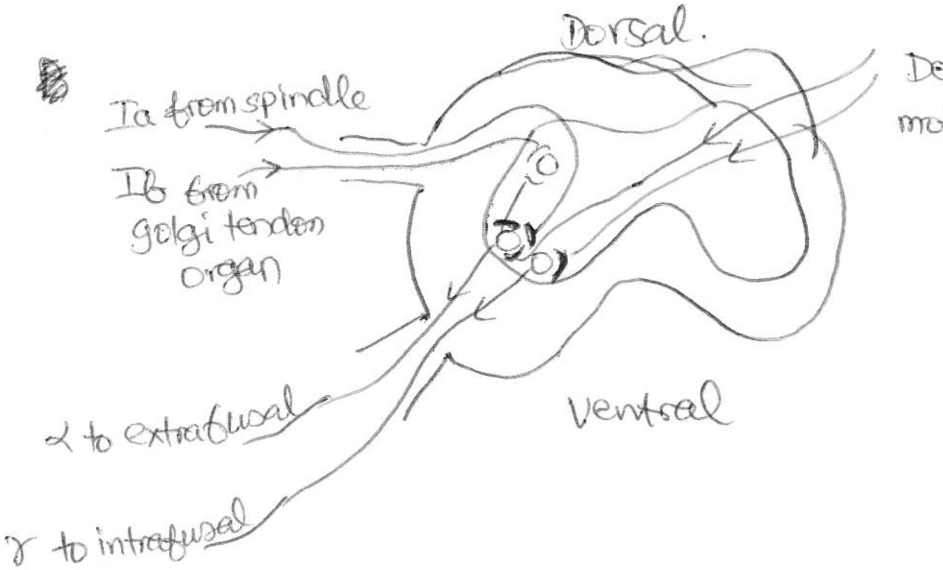
Lecture #7

Last lecture : Muscle model + tension-velocity curve.

This lecture : Reflex structure for a single muscle.

↳ only a few lectures to multi-muscle control.



α, γ : motor neurons.

- Reflex wiring goes thru' a few neurons (sometimes only one) in the SC.

- Ia signal feeds directly into motorneurons

↳ Stretch reflex (tapping patellar tendon) : can be fast becos there is only one neuron in betwn. Fastest response : 30 ~ 50 ms.

self-correction mech. under external force disturbance.

↳ Does it interfere w/ voluntary mvts?

Descending signals → α activation → muscle contraction

→ slack of muscle spindle → reflexive turn-off of α-activation

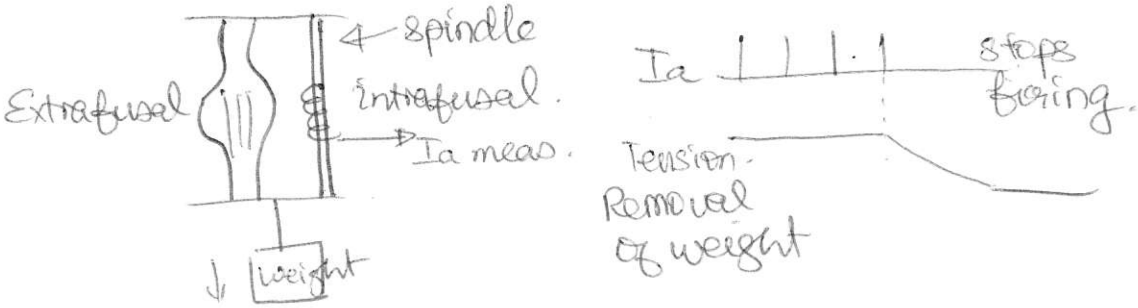
How can it be solved?

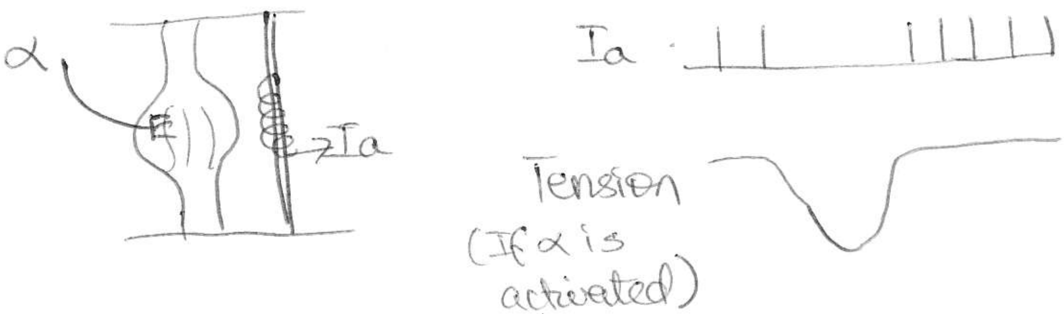
Activation of ~~α~~ simultaneously to γ if intrafusal fibers shorten at same time.

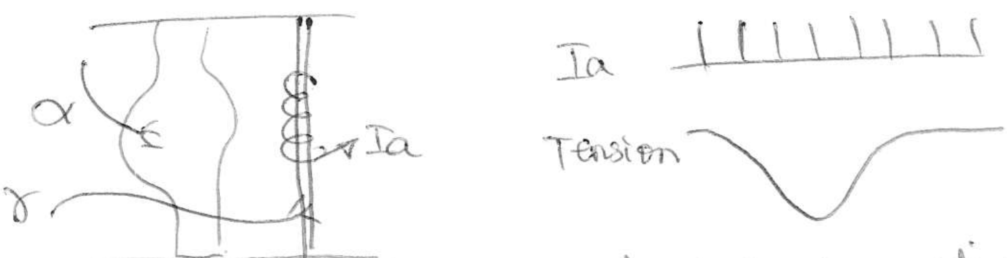
There is no slack in spindle.

γ neurons do not receive signals from Ia

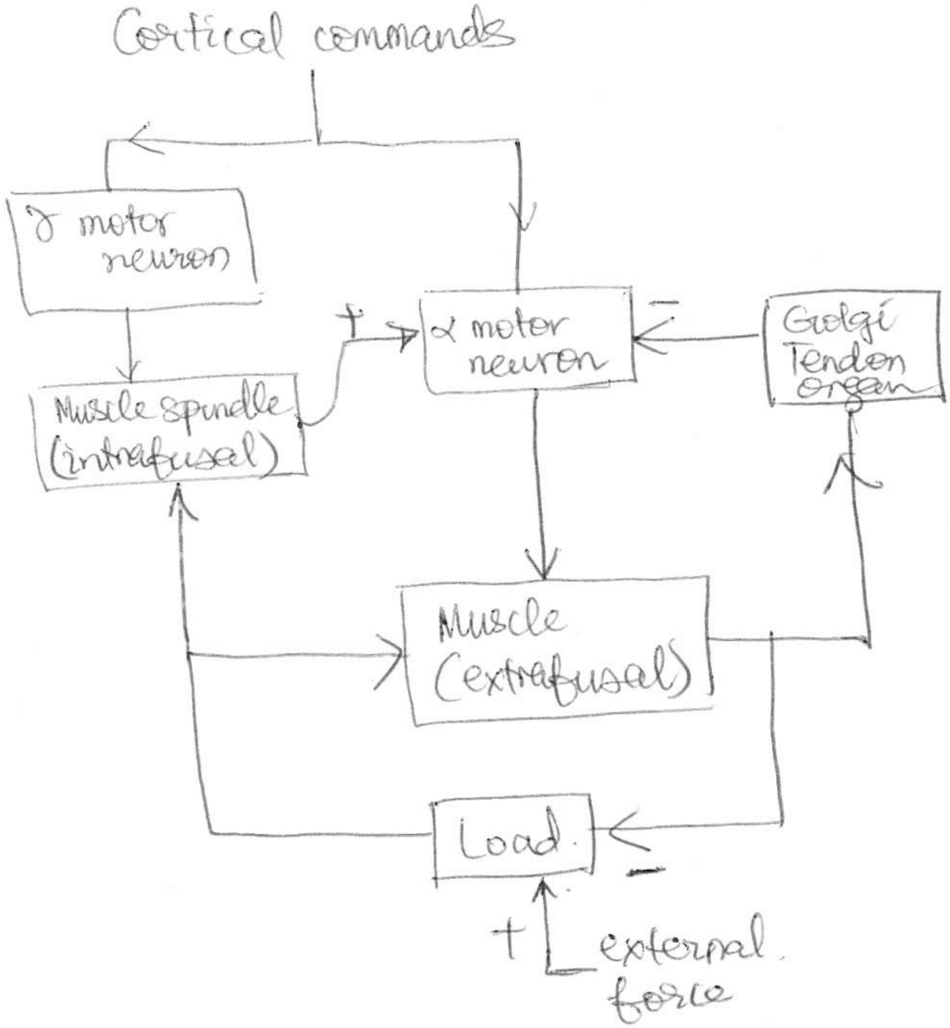
Remember:







Called α-γ co-activation

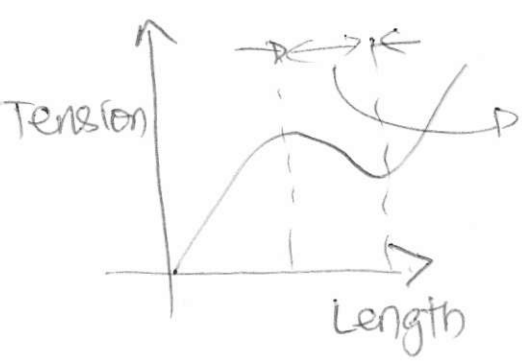


α-motor neurons keeps the balance/ratio of length & force

$$F = k(x - x_0) \Rightarrow k \propto \frac{F}{\Delta x}$$

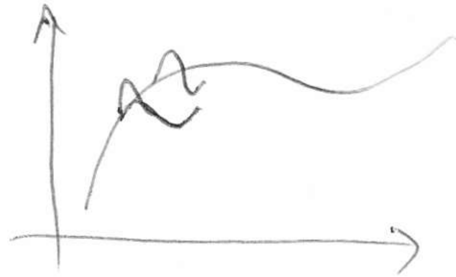
↳ keep ~ constant stiffness.

↳ allows stability when muscle operates on flat or negative curve on the tension-length curve.



If constant external force is applied w/o reflex, muscle would lengthen like a chewing gum and will be unstable

Another way muscle could be stable.



Constant velocity disturbance.
w/o reflex, crossbridges stretch & then let go to find new bonding sites
↳ causes negative curve.

Fatigue compensation w/ stretch reflex.

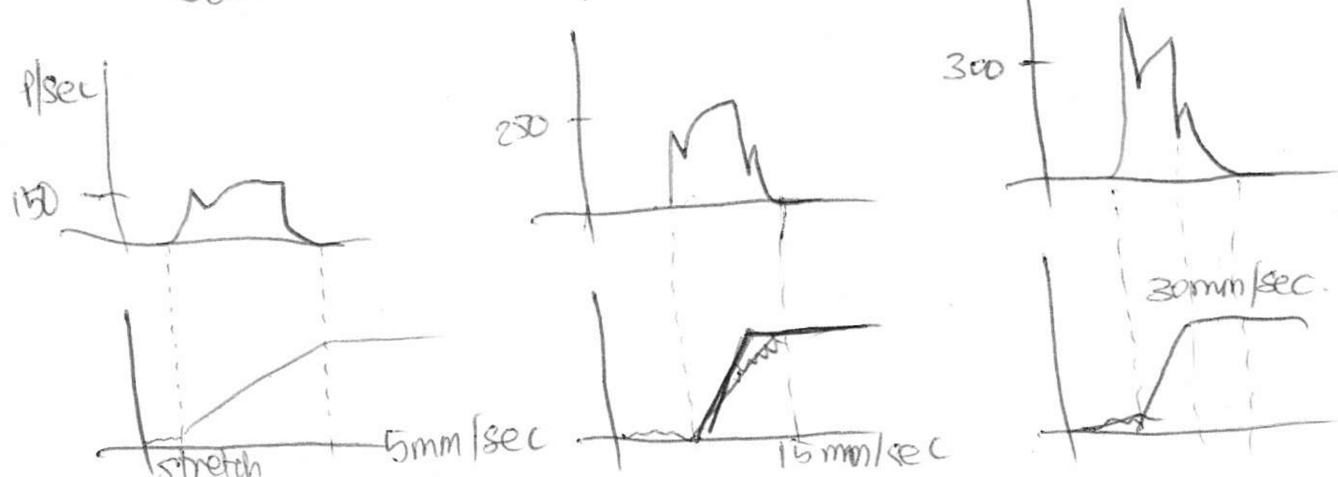
Imagine

for a long time

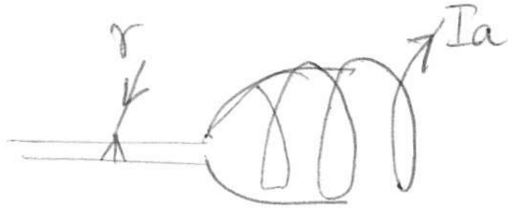
Length must stay the same. But the same activation produces less force overtime due to fatigue.

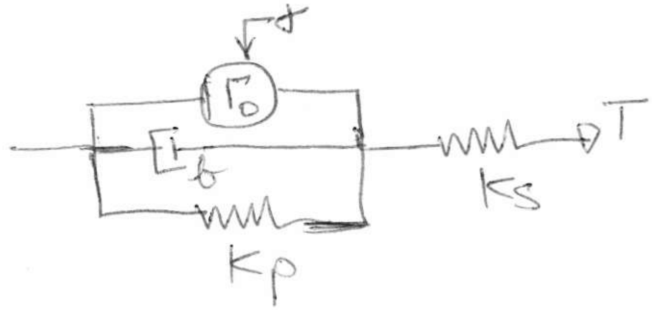
→ same input from spindle to α-neurons
but less input from tendon organ
→ must recruit more α-activations including other motor units.

Can we model the muscle spindle?
Look @ the response.



- Ia firing rate related to velocity
- Ia most sensitive to very small changes (< 0.1mm)
- reset after $V \Rightarrow 0$





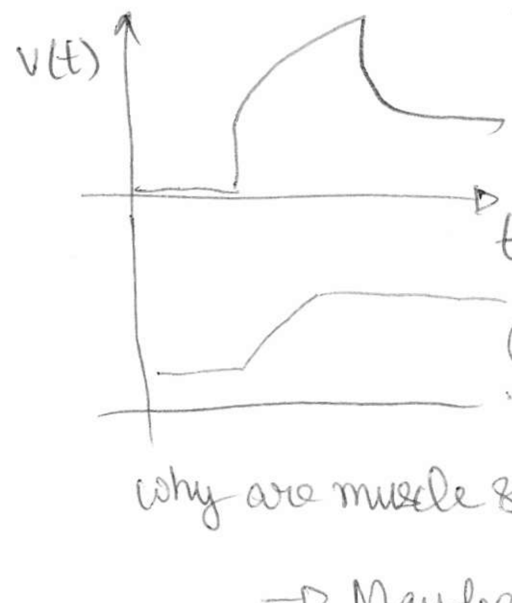
Ia discharge

freq $\Rightarrow V(t) = \dfrac{\Delta T}{K_s}$

If const. length change is imposed for x total(t), what happens to v(t)

$T = K_s x_s$

Takes most of the initial change that damped systems cannot take.



why are muscle spindles sensitive to velocity?

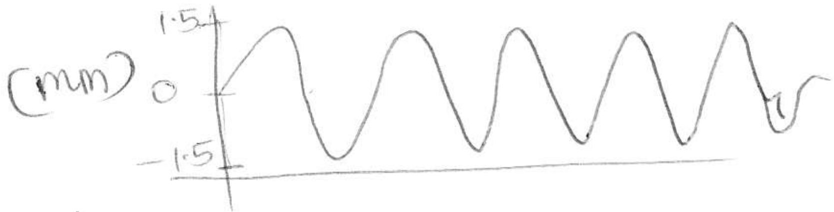
$\rightarrow$ Maybe to stabilize muscle.

I said muscle spindles detect stretch (posinal deviation)

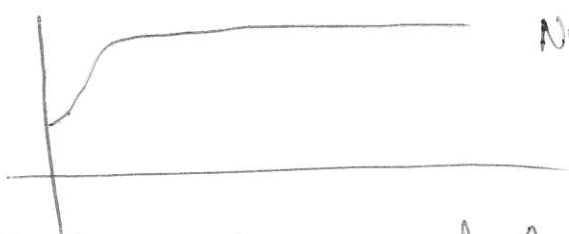
If there is only positional feedback to move a mass, the sys. oscillates forever (proportional control)

Velocity sensitive response from muscle spindles add a damping component to the control loop. (proportional + derivative control)

i.e. Tapping on index finger for 1.5mm ~~f~~ w/ 30msec cycle.



w/ the reflex loop cut off.



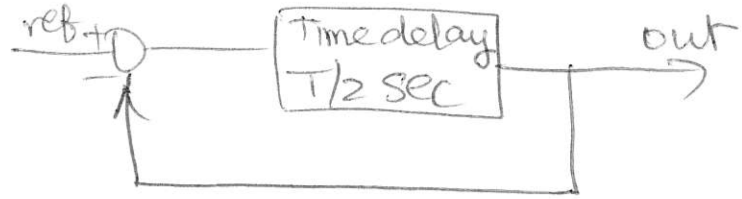
No oscillation, no return to original position

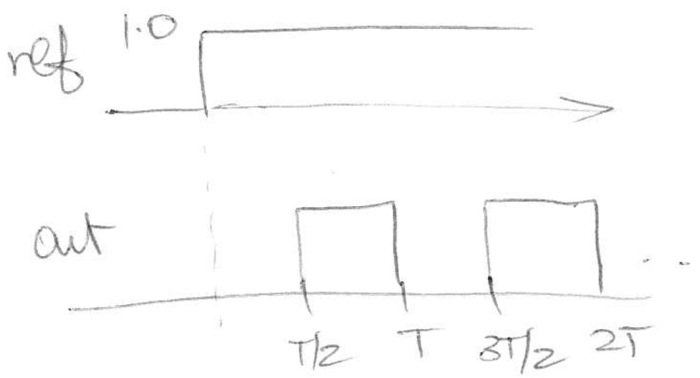
Thus, oscillation not caused by mechanical underdamping but from the reflex loop.

Another type of oscillation — tremor.

Most tremors (i.e. exhibited by Parkinson's)
have 2-3 Hz freq. → too slow to be caused by reflex loop
— most likely caused by some cortical lesions.

The effect of delay in Feedback Control Loop





Time delay can cause oscillation
If " " is too long, it may
overcome the damping effect
& oscillate severely