Lecture Notes 6

More muscle mechanics → models.

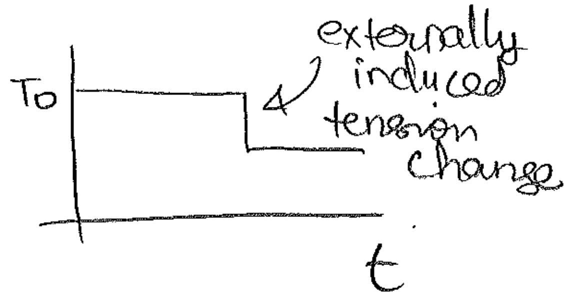
In an attempt to model muscle,

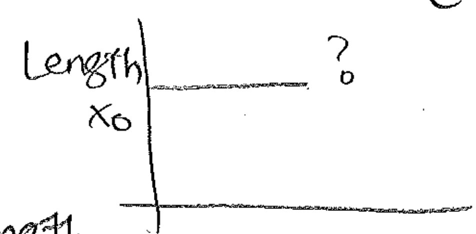
Quick Release expt.

Remember.

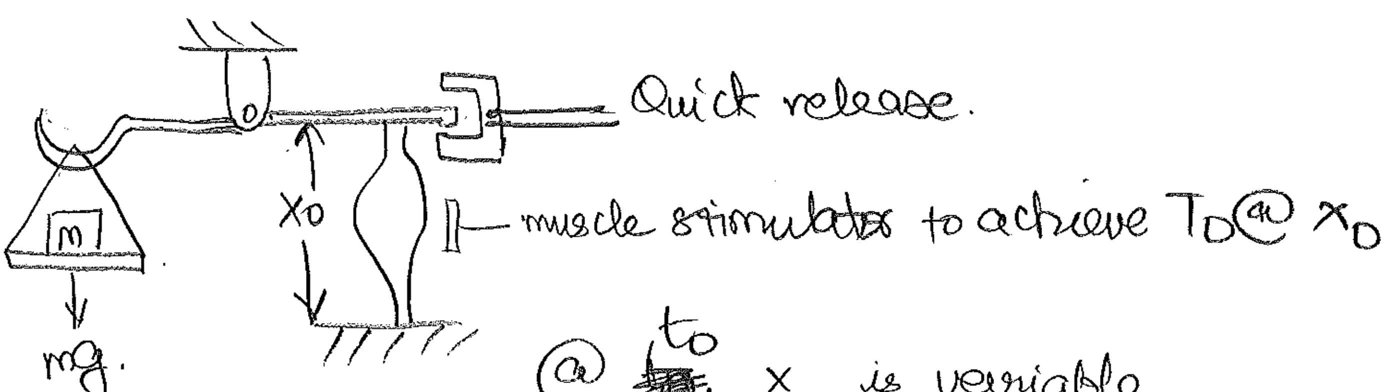
isometric condition

Contractile component alone.



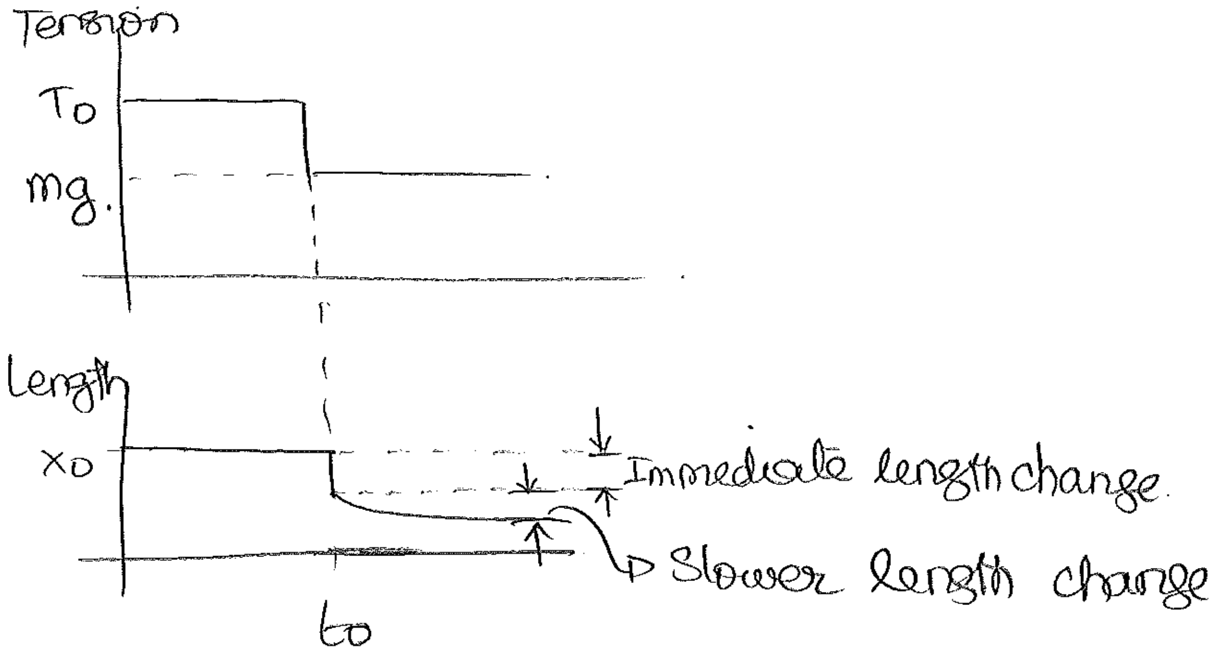


What would happen to length of muscle?

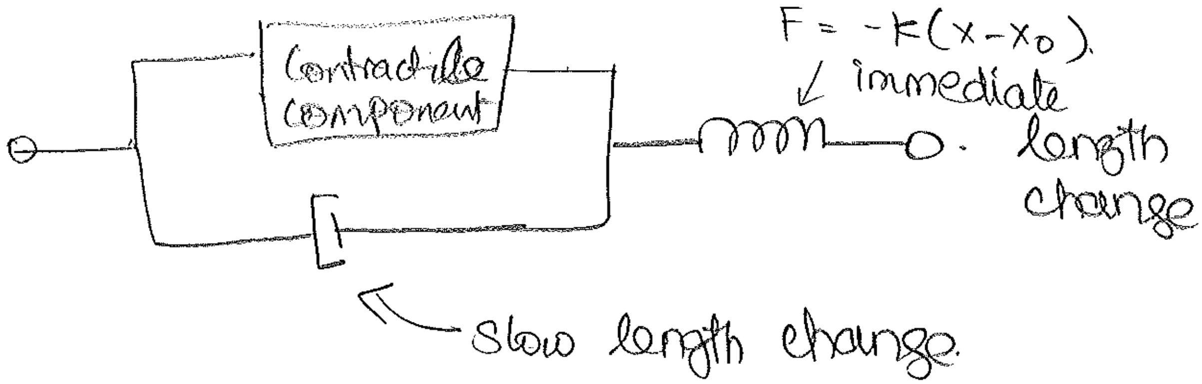


@ t_o, x is variable.

$T = mg$.

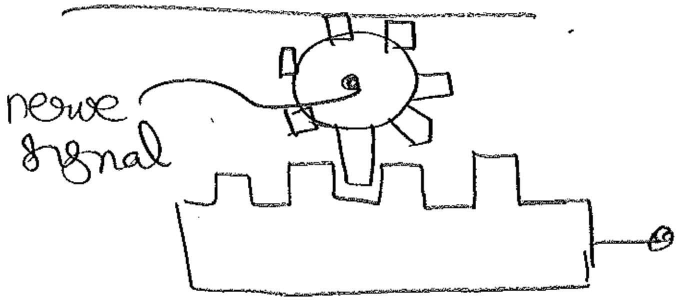


Model

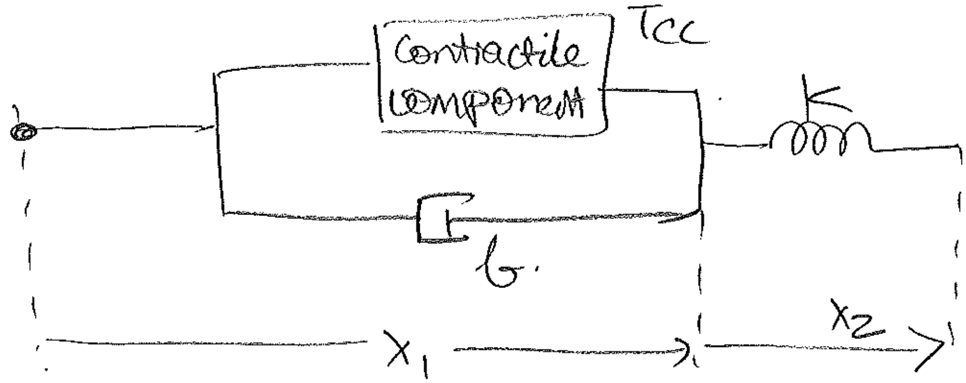


$F = b\dot{x}$

Contractile component

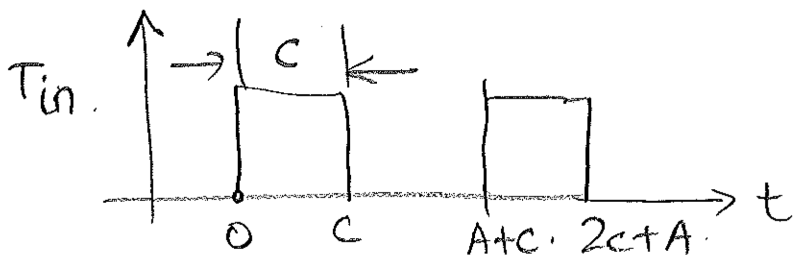


nerve receives signal & contracts.



Isometric $\Rightarrow$ $x_1 + x_2 =$ constant.

Contractile component receives pulse input



Tension $(t=0) = 0$

Tension $(0<t<c) = T_{in}$?

What is the tension for the whole sys. under an isometric condition as a function of time?

Use simple physics + differential eqn.

If whole muscle experiences tension T,

spring " $T = K\Delta x_2$ (1)

So as CC + dashpot

$$T = b\dot{x}_1 + T_{cc} \quad (2)$$

Remember isometric $x_1 + x_2 = \text{const}$ (3)

$$\Downarrow$$

$$\dot{x}_1 + \dot{x}_2 = 0.$$

Differentiate (1) $\dot{T} = k\dot{x}_2$

$$\Rightarrow \quad \dot{x}_1 = -\dot{x}_2 = -\dot{T}/k$$

$$\Rightarrow \quad T = b\left(-\dot{T}/k\right) + T_{cc}.$$

$$\Rightarrow \quad T + \frac{b}{k}\dot{T} = T_{cc}.$$

For $t < 0$, $T = 0$.

$0 \le t \le c$, $T_{cc} = T_{in}$, $T(0) = 0$

$$T(t) = T_{in}\left(1 - e^{-kt/b}\right)$$

@ $t = c$

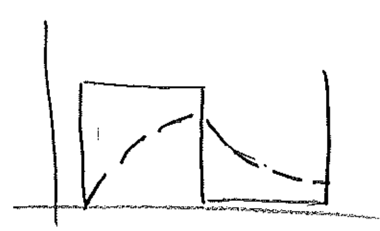
$$T(c) = T_{in}\left(1 - e^{-kc/b}\right).$$

For $c \le t \le c + A$, $T_{cc} = 0$, $T(c)$.

$$T(t) = T(c)\left(e^{-k(t-c)/b}\right).$$

@ $t = c + A$

$$T(c+a) = T(c)\, e^{-kA/b}.$$

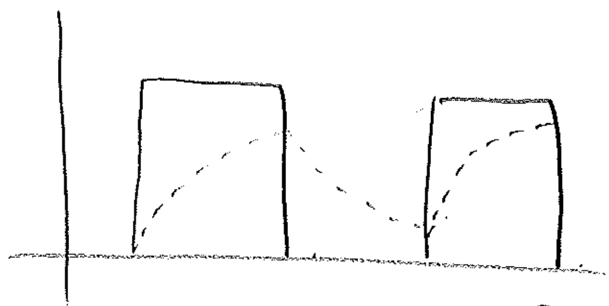


Now @ $C+A \le t \le 2C+A$.

$T_{cc} = T_{in}$ again but @ $t = C+A$.

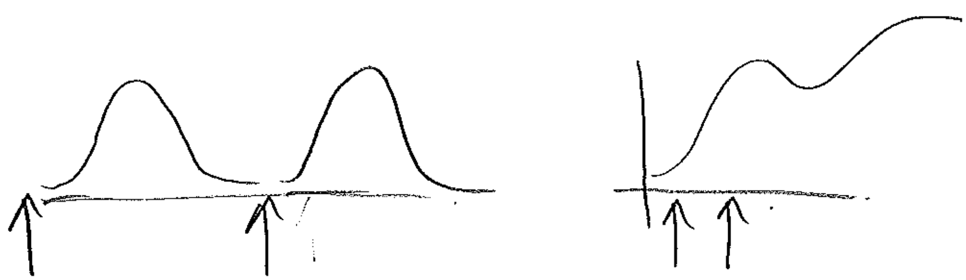
So it is a superposition of 2 responses.

$$T(t) = \underbrace{T(c)\,e^{-k(t-c)/6}}_{\text{Still decaying.}} + \underbrace{T_{in}\left(1-e^{\frac{-k(t-c-A)}{6}}\right)}_{\text{new response}}$$



$T(2C+A) > T(c)$

Explains two-twitch response expt.



The tension @ 2C+A → Tmax

How do they change w/ $A \to 0$?
$A \to \infty$.

$$T(2C+A) = T(c)\,e^{-k(c+A)/6} + T_{in}\left(1-e^{kc/6}\right).$$
$$= T_{in}\left(1-e^{-kc/6}\right)\left(1+e^{-k(A+c)/6}\right)$$

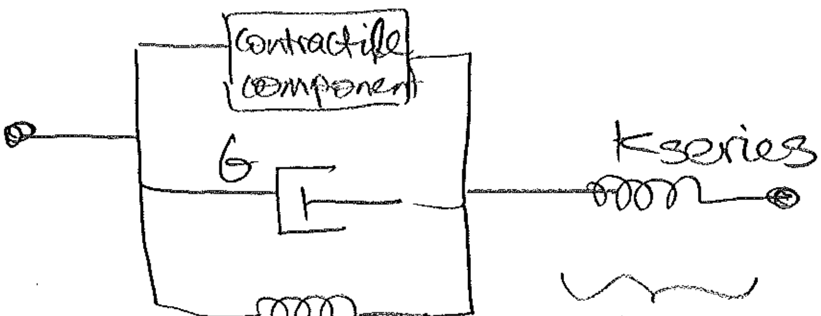
When $A \to 0$ $\quad T(2C+A) = T_{in}(1-e^{-2KC/G})$

continuous stimulation

$A \to \infty$ $\quad T(2C+A) = T_{in}(1-e^{-KC/G}) = T(C)$

Same as if first stimulation did not exist

Full muscle model (also called Hill's model)

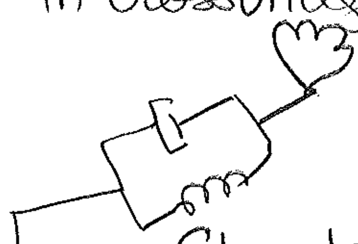


in sarcomeres & tendons.

Kparallel

$\underbrace{\qquad\qquad}$

in crossbridges.



filaments, connective tissues etc.

Kp & KS make up all the passive characteristic
↓
elastic.

So far we have covered

Tension Vs time

length.

How about velocity?

lightweight → fast

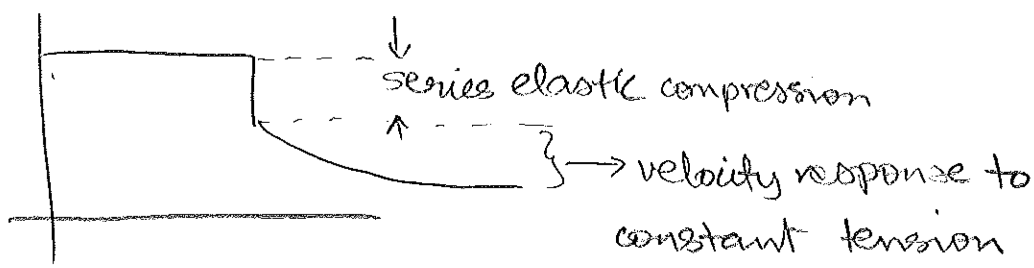
heavy weight → slow

Very heavy weight → can hold it but cannot lift

Muscle tension depends on velocity

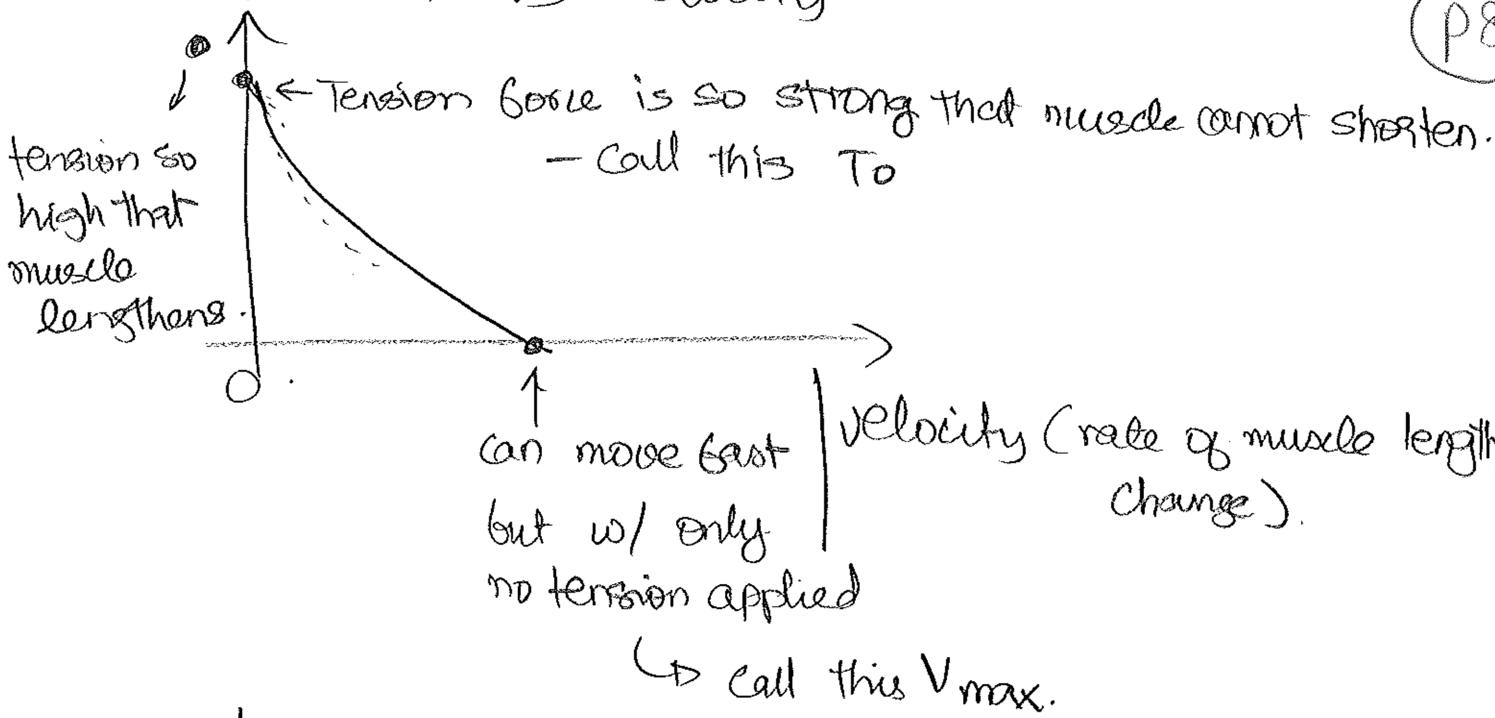
" can produce more force isometrically than when actively shortening

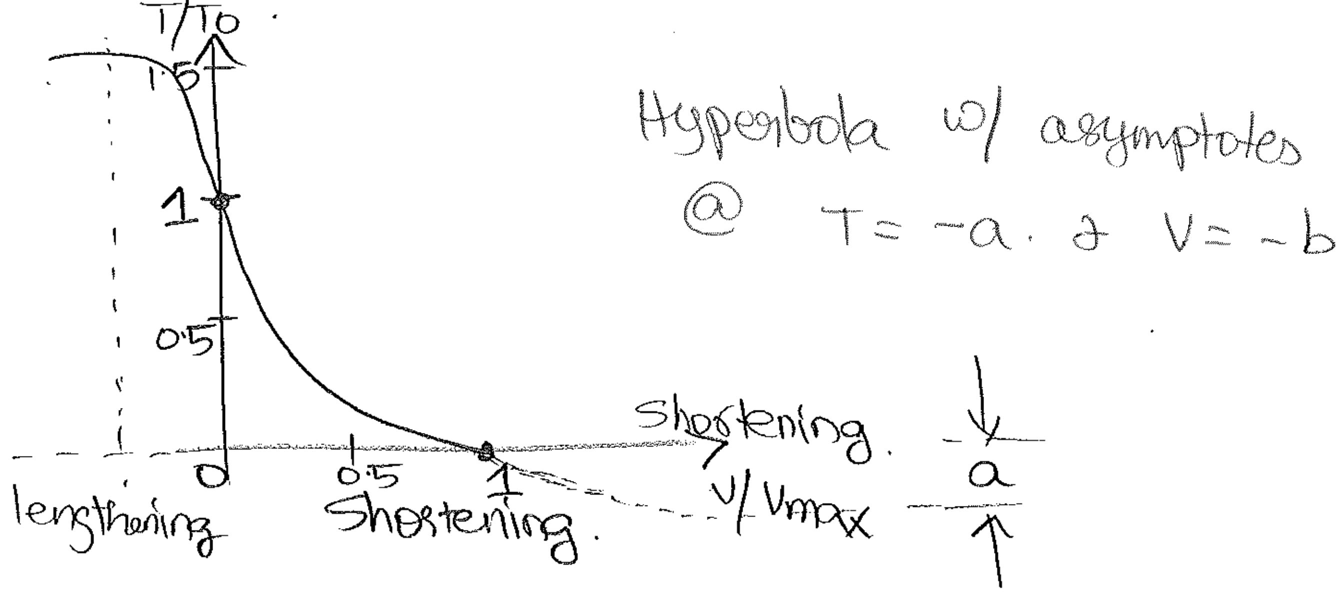
Remember in quick release.



purely in the contractile + damper component.

Tension Vs Velocity





Normalized Eqn. (Hill's equation)

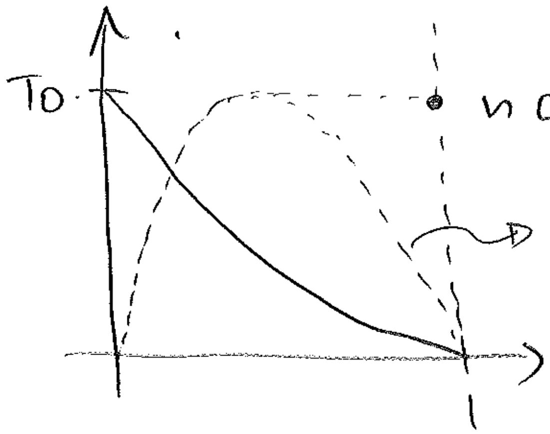
$$V' = (1 - T')/(1 + T'K)$$

where $V' = \dfrac{V}{V_{max}}$, $T' = T/T_0$, $K = \dfrac{a}{T_0} = \dfrac{b}{V_{max}}$

K in the range of 0.15 – 0.25

works well for vertebrate muscles

Power = FV ⇒ $T_0 V_0$



Max power @ 20-30% of V_{max}.

- ~~similar to~~ apply to bicycle gears which allows people to take advantage of this peak.

Muscle lengthening curve is also useful when stopping - explains curve in the negative region

When muscle is @ tetanus activation + applied T is larger than T_0, muscle actively lengthens