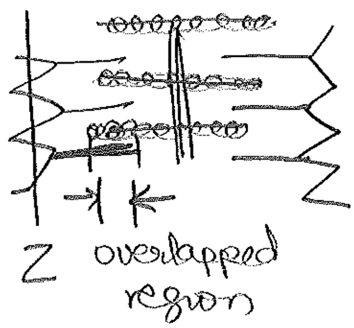
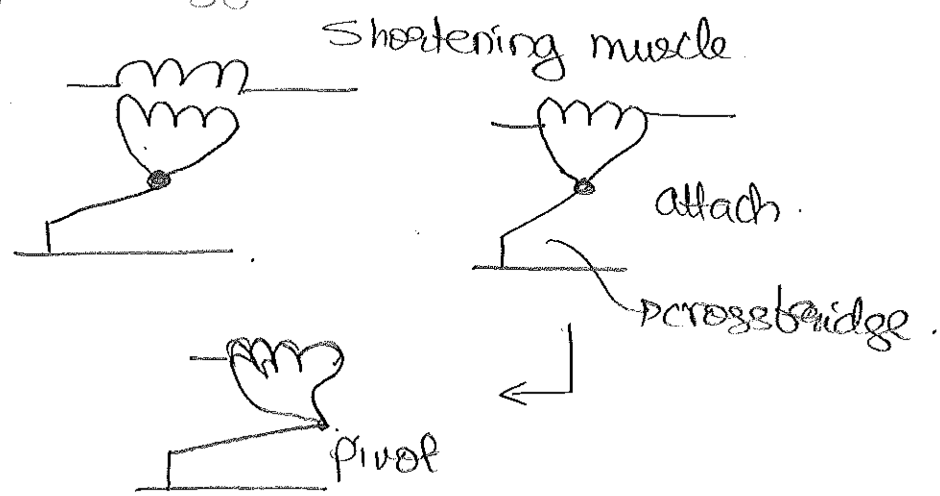
Lecture Notes 5

Muscle Mechanics & Models

Remember muscle physiology.





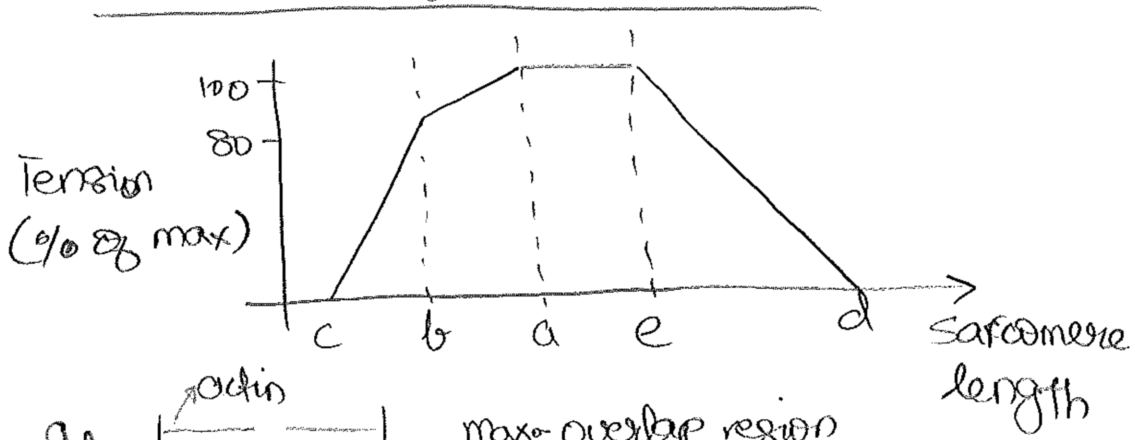
Remember lengthening motion is passive

Muscles produce force

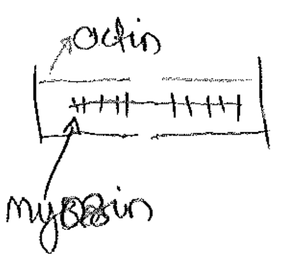
↳ where does it come from?

The crossbridges. ⇒ more crossbridges ⇒ more force.

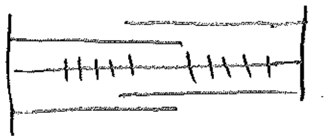
Gordon, Huxley, Julian (1966)



a.



max. overlap region btwn actin & myosin filaments ~ 2.0 μm

b. 

One sarcomere is exactly the length of one myosin filament (P2)

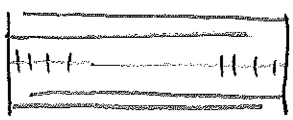
(z disk collides w/ myosin fil.)

~ 1.67 μm

betwn a & b, actin filaments interfere w/ each other

⇒ shorter, the more interference

(linearly decreases)

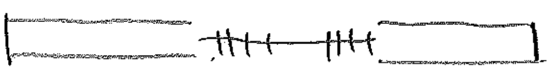
C. 

Myosin filament get crumbled or folded @ the end

No myosin heads can stay connected.

and the force → 0.

~1.27 μm

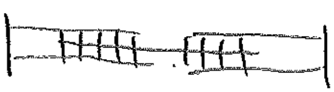
d. 

No myosin-actin overlap ⇒ no force

~ 3.65 μm

Betwn d & e : less & less overlap ⇒ linearly decr w/ tension

What is e?

e. 

Myosin filament has no myosin heads in the middle.

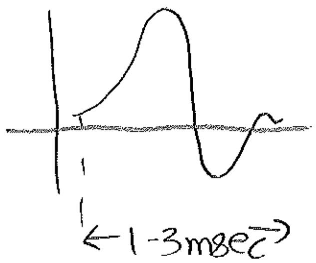
So there is a plateau region

~2.25 μm. (betwn a & e : close to muscle rest length)

↳ this plateau used as evidence that crossbridges generate muscle force

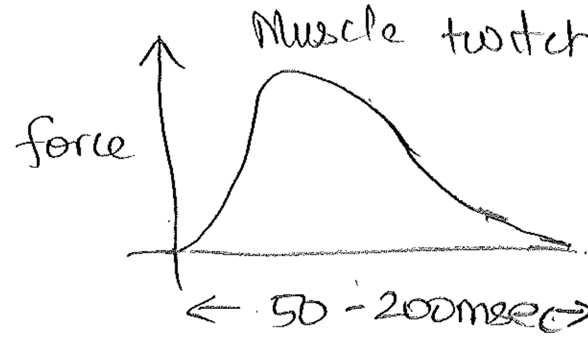
How do muscle fibers contract?

- with electrical signals from the motor axons



~15 msec latency

Muscle twitch

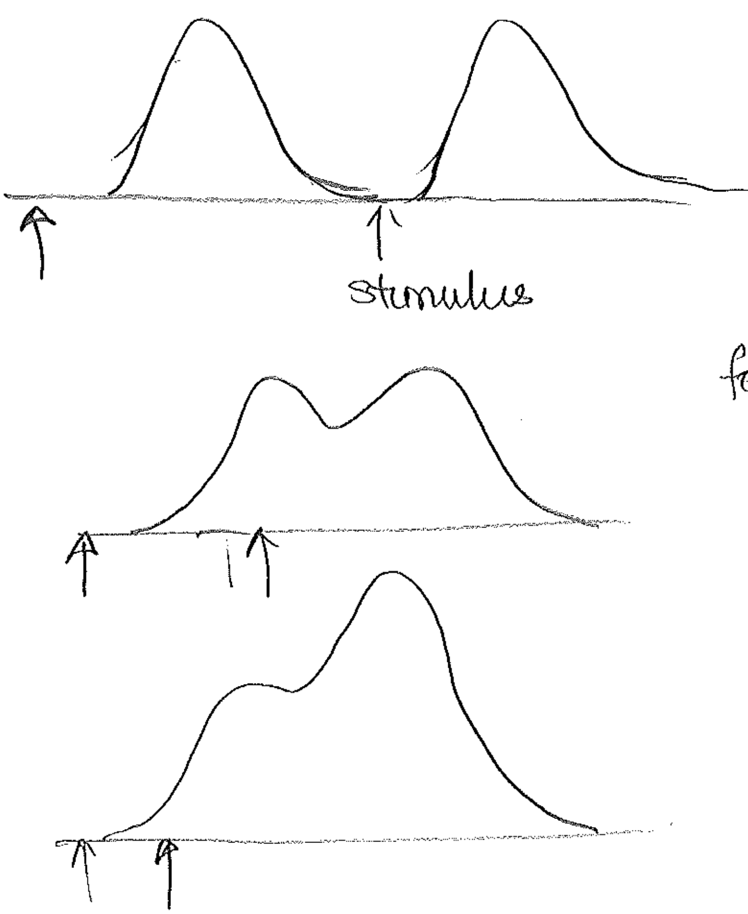


Muscle twitch lasts a long time

→ Ca^{2+} to get pumped in & out of sarcoplasmic reticulum.

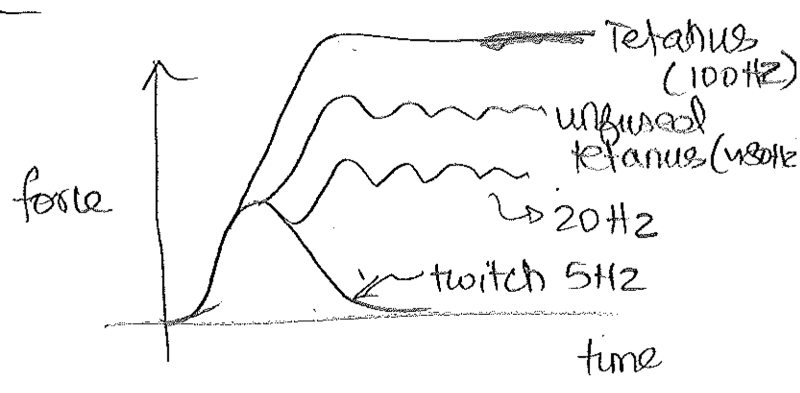
So how to produce more force ~~mo~~ continuously?

More force - two twitch experiment



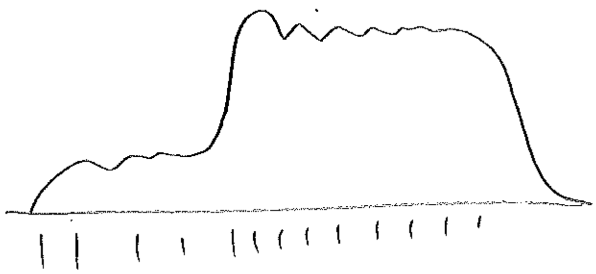
More continuously?

How close shd stimuli be?

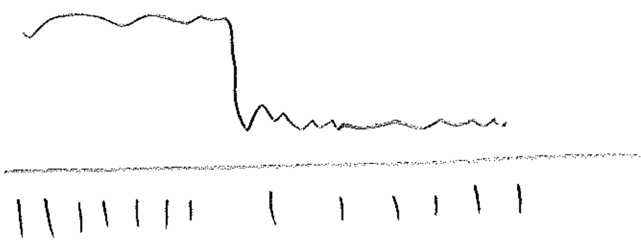


How to vary the force?

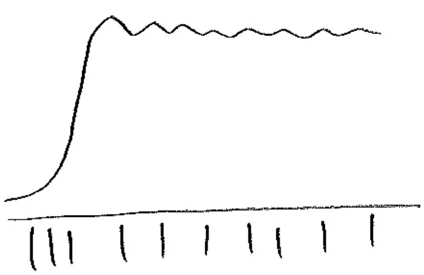
Add or subtract nerve impulse.



extra impulses increase the force.



Missing impulses decreases the force



Adding impulses @ the beginning increases the force & rate of change drastically

Do all muscles respond the same way? No!

Three types of fibers
- Slow
- Fast fatigue-resistant
- Fast fatiguable

In order to explain performance/response of these fibers, need to explain the concept of a "motor unit."

One muscle fiber is innervated by only one motor neuron

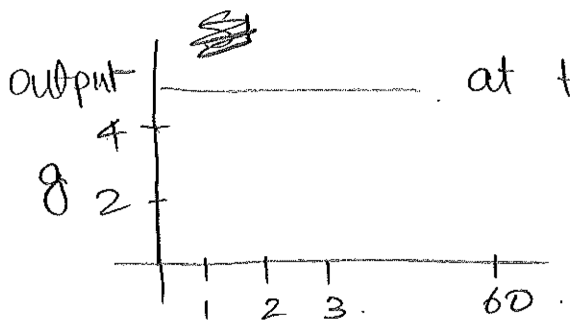
One motor neuron innervates multiple muscle fibers.
(sometimes even in diff. muscles)

~~This~~ motor unit : one motor neuron, its axon, & all muscles its innervates : smallest functional motor unit

Fibers belonging to a motor unit are always the same type.

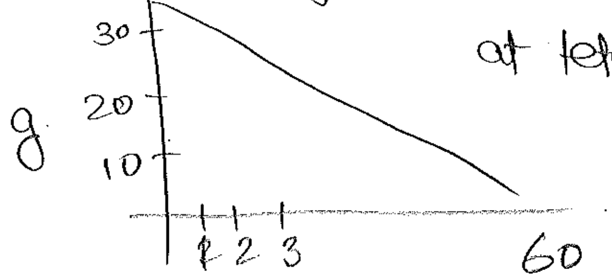
So stimulating one motor neuron exhibits one of three behaviors.

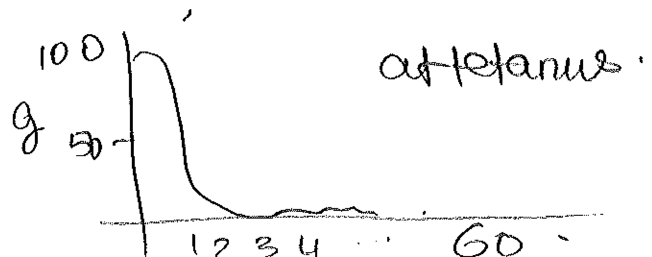
Stimulating a motor neuron connected to slow fibers
(slow units)



Narrower axons
Smaller motor neuron

Fast - Fatigue resistant units





Taller axons (conduct faster)
Larger motor neuron
(takes more time to activate)

Each muscle contains all three units

Slow units are recruited first

↳ takes less time to actuate

↳ easier to modulate force

↳ slow units used all the time & FF is a supplement.

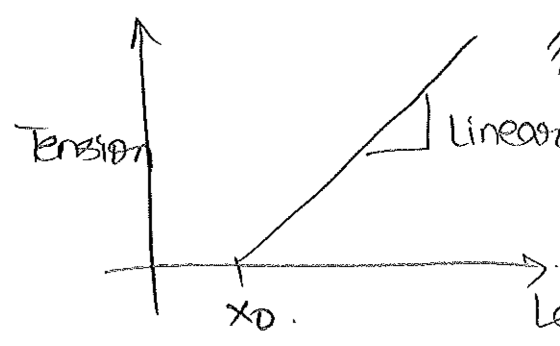
[Functional electrical muscle stimulation seems to actuate fast muscles, which tire quickly. So not very effective]

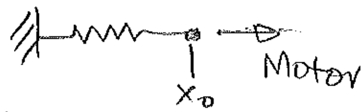
Now focus on muscle as a whole, rather than @ fiber level.

<u>Think of a spring</u>

$F = -k(x - x_0)$

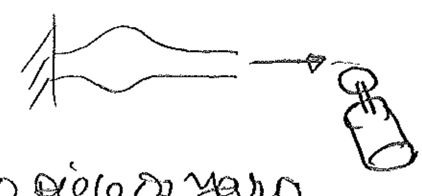
If k = constant:

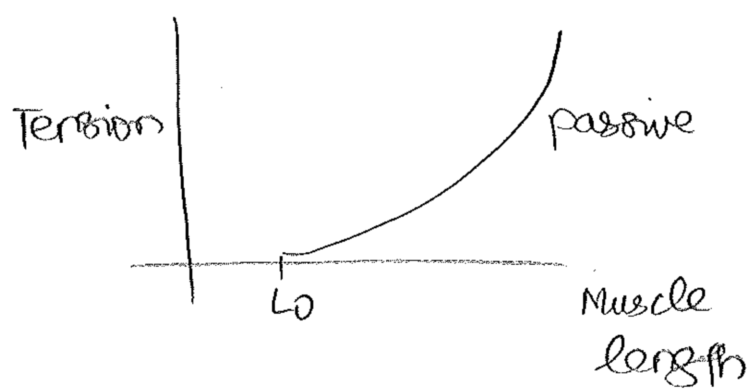




<u>Passive muscle (no nerve signal).</u>

Tension = 0 @ rest (L_0)

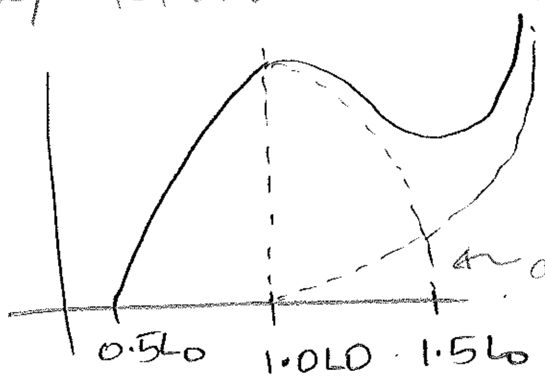




Similar to piece of yarn

→ recruits more springs in ∥el w/ stretch.

Now w/ tetanus activation

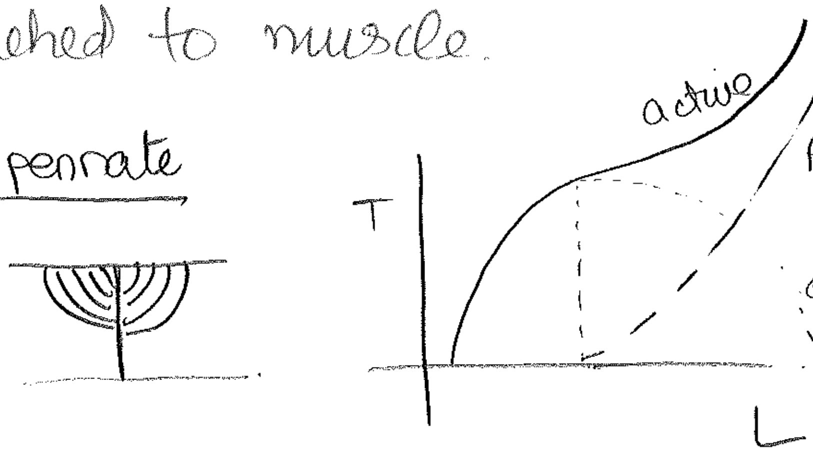


Constant stimulation

active − passive = developed tension comes from crossbridges

The ratio of developed & passive tension changes depending on amt. of connective tissue/tendon attached to muscle.

Bipennate



Parallel