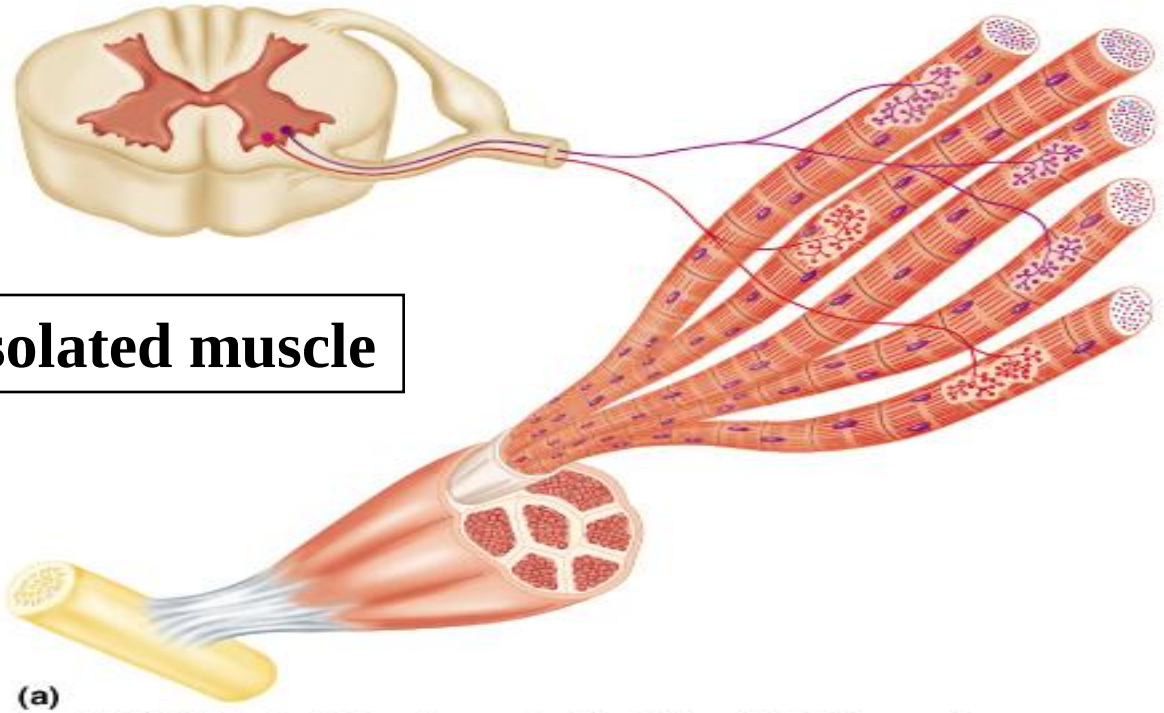
Skeletal Muscle Physio.

***in vivo* - living organism**

***in vitro* - isolated muscle**

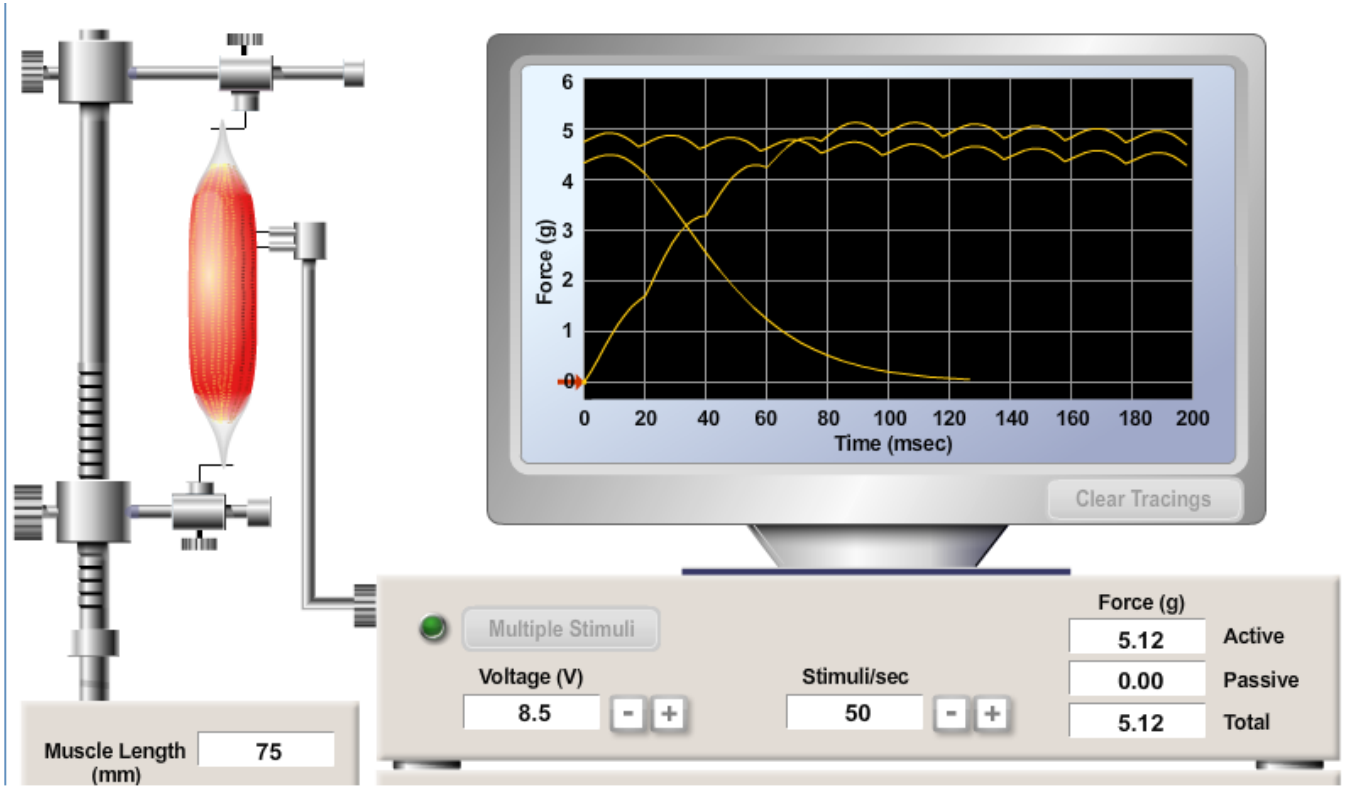


(a)

Lab Setup

1) biological material:
a) pithed frog - exposed muscle or b) isolated skeletal muscle

2) oscilloscope : stimulating & recording electrodes



Lab Results Summary

1) single stimulus:

- ↑ stimulus intensity -> stronger muscle twitches

2) multiple stimuli:

↑ stimulus frequency -> graded muscle resp.

3) isometric contractions (muscle length changes)

a) shortened & stretched muscles -> less force

b) natural length muscles -> most force

4) isotonic contractions (weight changes)

a) lighter weights – faster & longer pickup

b) heavier weights – slower & shorter pickup

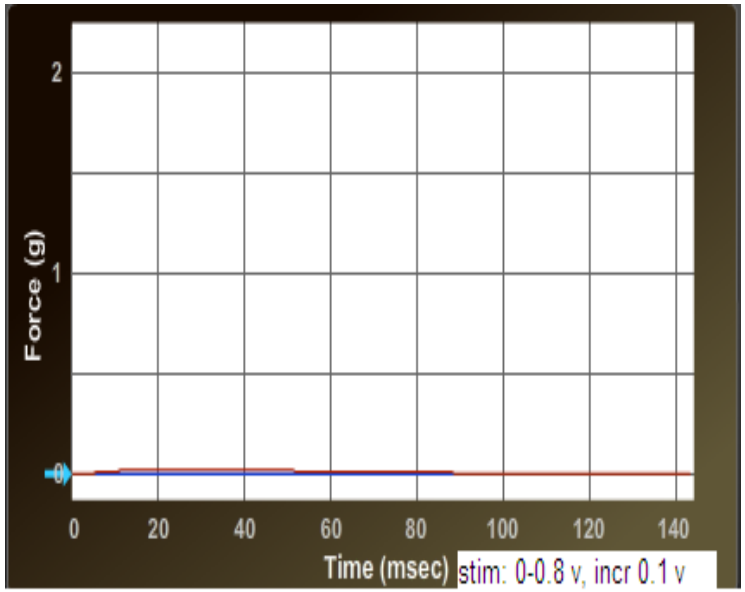
Stimulus Strength Δ

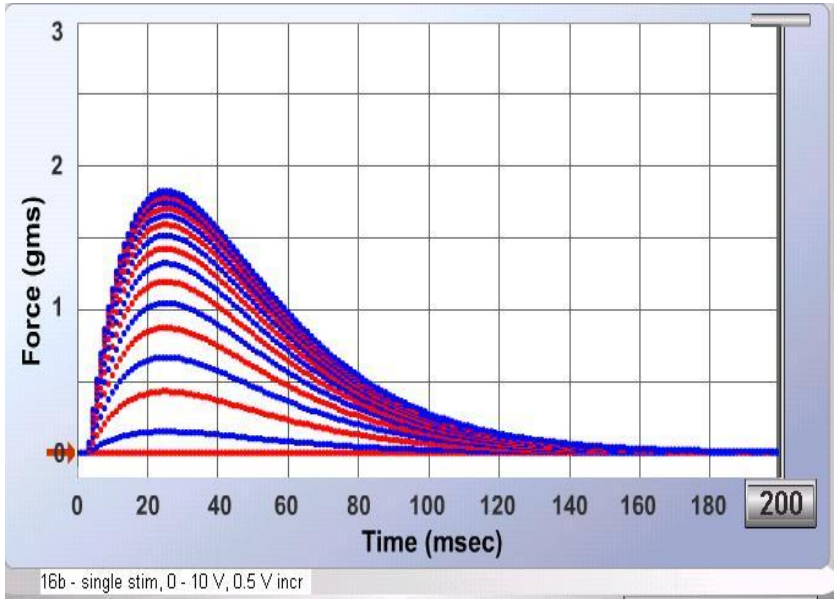
↑ stimulus strength -> stronger muscle twitches

Stimulus Range:

below threshold
- no twitch

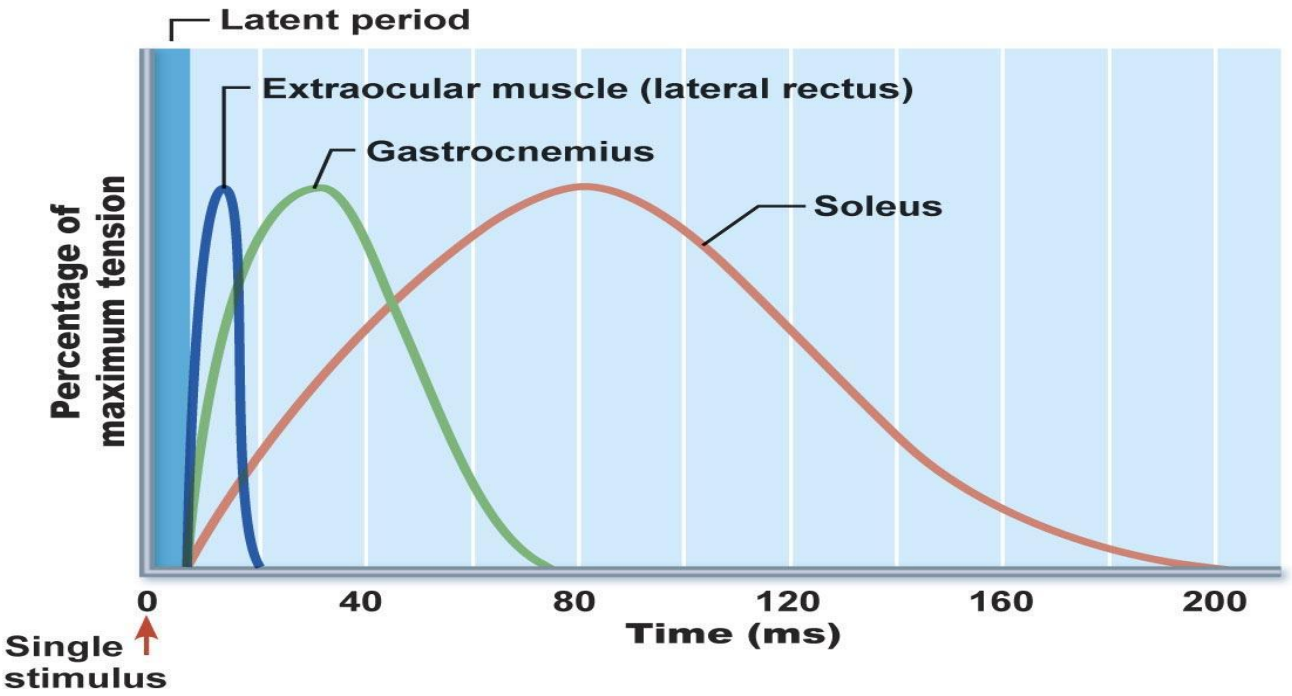
threshold to maximal
- stronger twitch, to limit





Twitch Duration & Speed (1)

3 muscle fibers: fast glycolytic, fast oxidative, slow oxidative



(b) Comparison of the relative duration of twitch responses of three muscles

note: y = % max. tension, not muscle force (g)

Twitch Duration & Speed (2)

1) **extra-ocular muscle: short and fast twitch**
   - **move and rotate eyeball**
   - **mostly fast glycolytic fibers (white)**

2) **gastrocnemius (calf): in-between twitch**
   - **flex foot and knee**
   - **mostly fast oxidative fibers (pink)**

3) **soleus (calf): long and slow twitch**
   - **flex foot, posture in running**
   - **mostly slow oxidative fibers (red)**

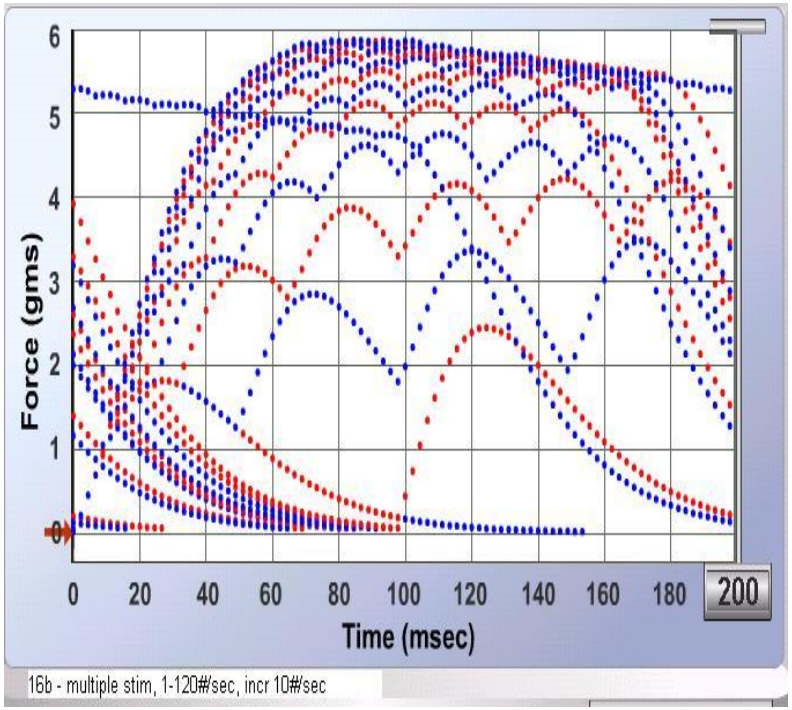
*** each muscle: diff. distrib. of 3 muscle fibers**

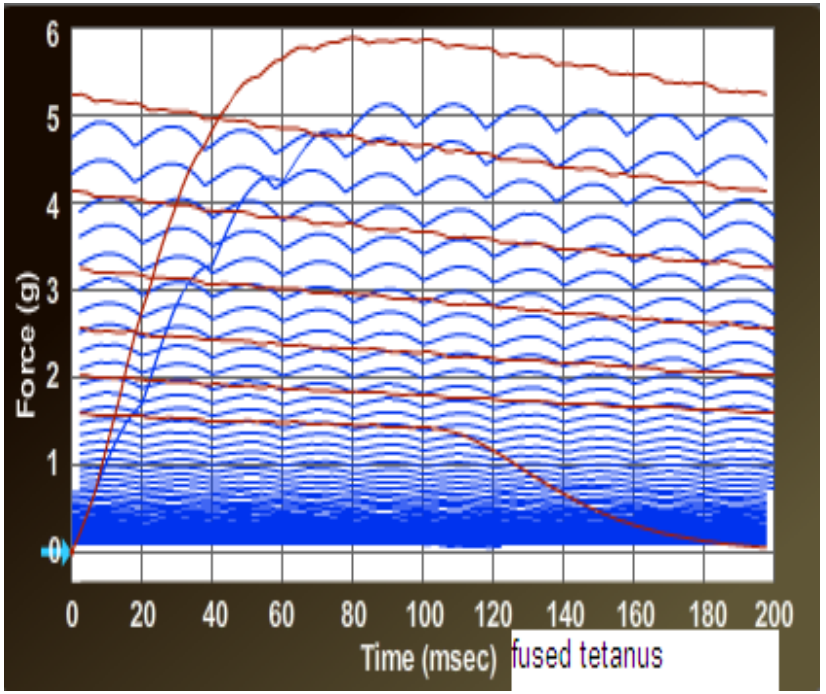
Muscle Fiber Types (1)

feature	red	pink	white
1) metab.	slow oxidative	fast oxidative	fast glycolytic
2) capillary	extensive	medium	sparse
3) ATP	aerobic	aerobic	anaerobic
4) fatigue	slowly	medium	quickly
5) site	trunk, calf	legs	arms
6) activity	run, posture	walk	lift, spring

Stimulus Frequency Δ

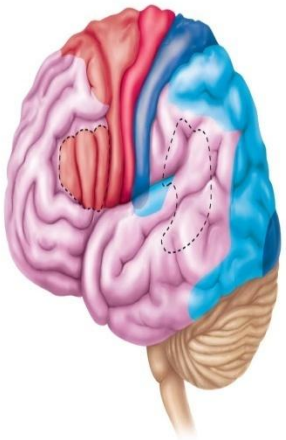
↑ stimulus frequency -> graded muscle resp.
- wave summation graphs: treppe, unfused and fused tetanus, fatigue

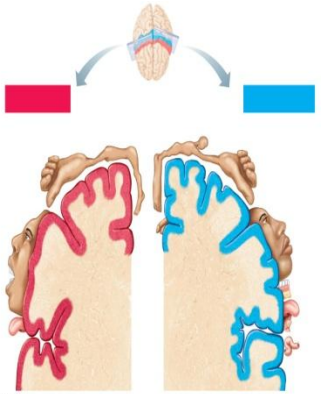




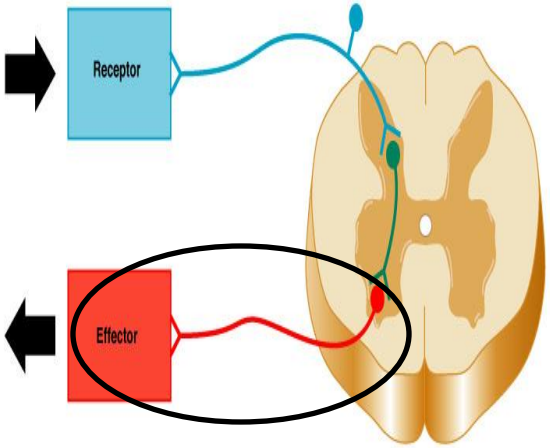
Neural Circuit - Muscle Response

CNS: motor cortex, descending tract



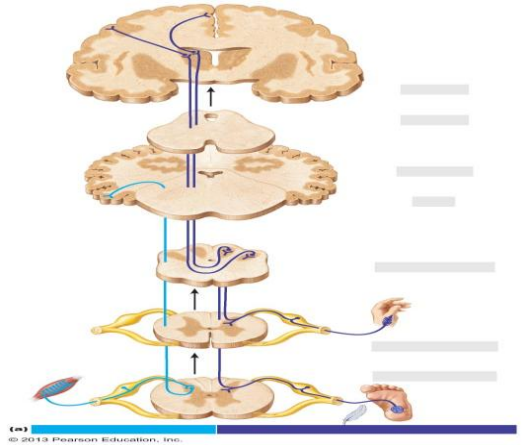


Stimulus

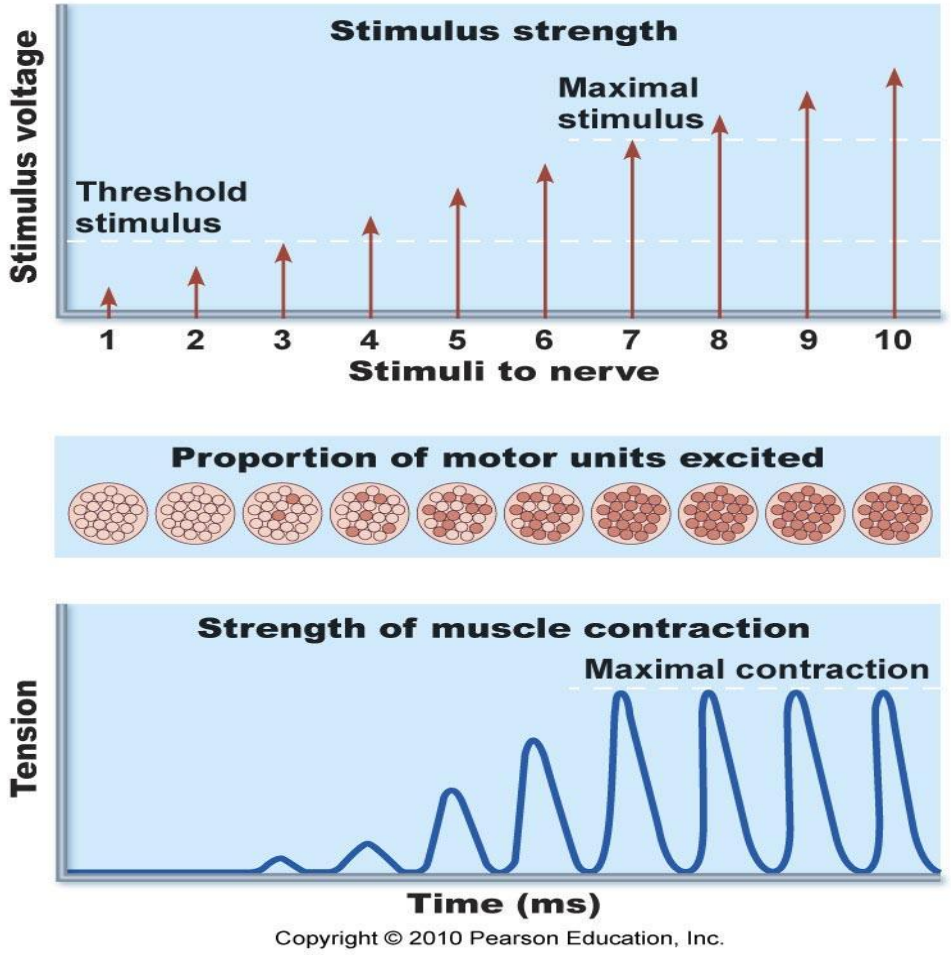


Response (muscle contracts)

(motor unit)



Recruitment
(motor unit summation)

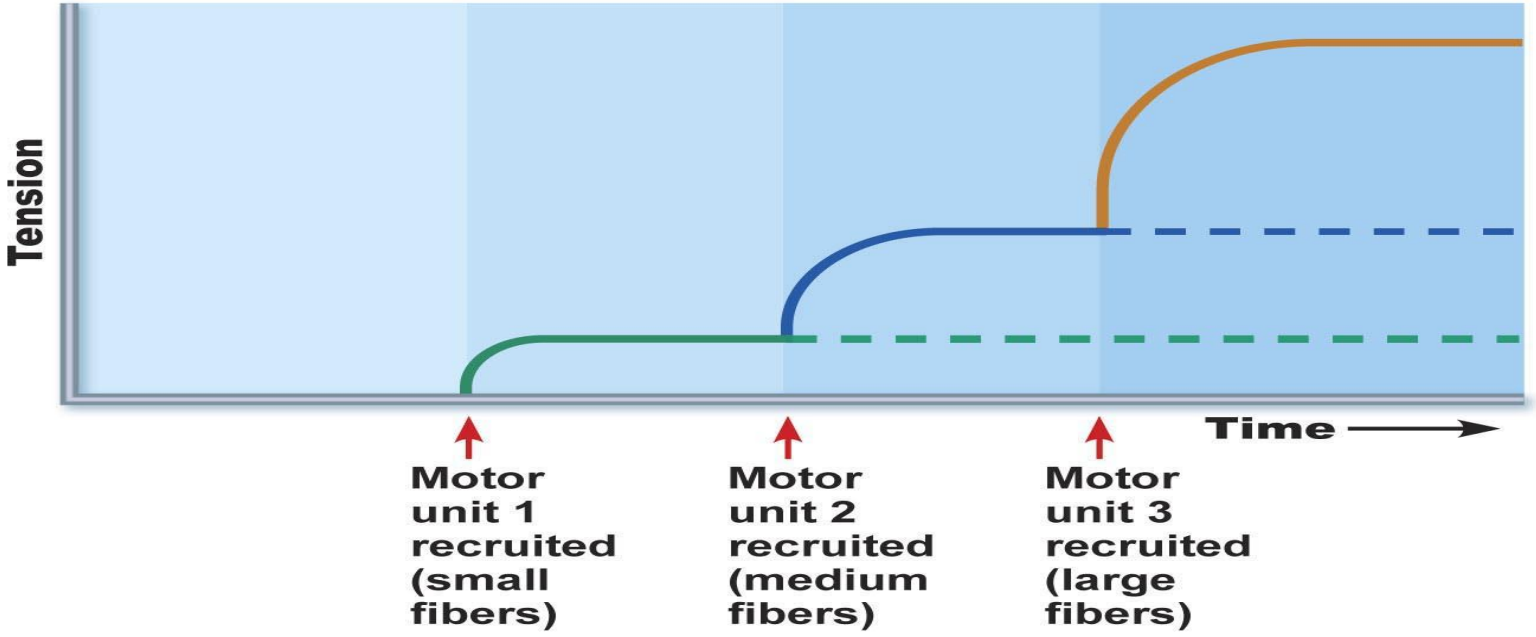


<u>stimulus range</u>:
threshold ->
maximal

<u>recruitment</u>:
↑ stim. intensity
-> ↑#motor units
-> ↑tension
(max # units =
max. force limit

Recruitment (motor unit size)

recruitment sequence:
smallest (least force & fatigue) -> largest (most)
- muscles have all 3 motor unit sizes
- energy conservation; reduce fatigue



Terms (1)

1) twitch
   - one stimulus
   - one sized contraction
   - explosive build-up
   - prod. ↑ force by ↑# motor units
   - due to ↑stimulus intensity

2) wave summation
   - multiple stimulus
   - many, diff. sized contractions
   - slow build-up
   - prod. ↑ force from same motor units
   - due to ↑ stimulus freq. (rate)
   = temporal summation (added in time)

Terms (2)

3) tetanus

- example of wave summation

- tetanus - incl. uninterrupted, sustained contractions

- incomplete or unfused tetanus - prior to tetanus

- needed in "work": muscle contraction force > load

- prod. from same # motor units

4) motor unit summation

- recruit: prod. ↑force from ↑ # motor units

- stimulus range: (↑ stimulus intensity; muscle limits)

a) threshold = min. stim. intensity for response

b) max. stimulus = max. stim. intensity for response

- no stronger response as all motor units recruited

Muscle Force

muscle contractions
→ muscle force to hold or move weights

1) isometric contractions
- hold weights in position
- posture (body weight)
eg pitching position, push wall
- stationary load
eg hold dumb bell

2) isotonic contractions
- move weights a distance
- lift weight eg move baby up or down

Muscle Length

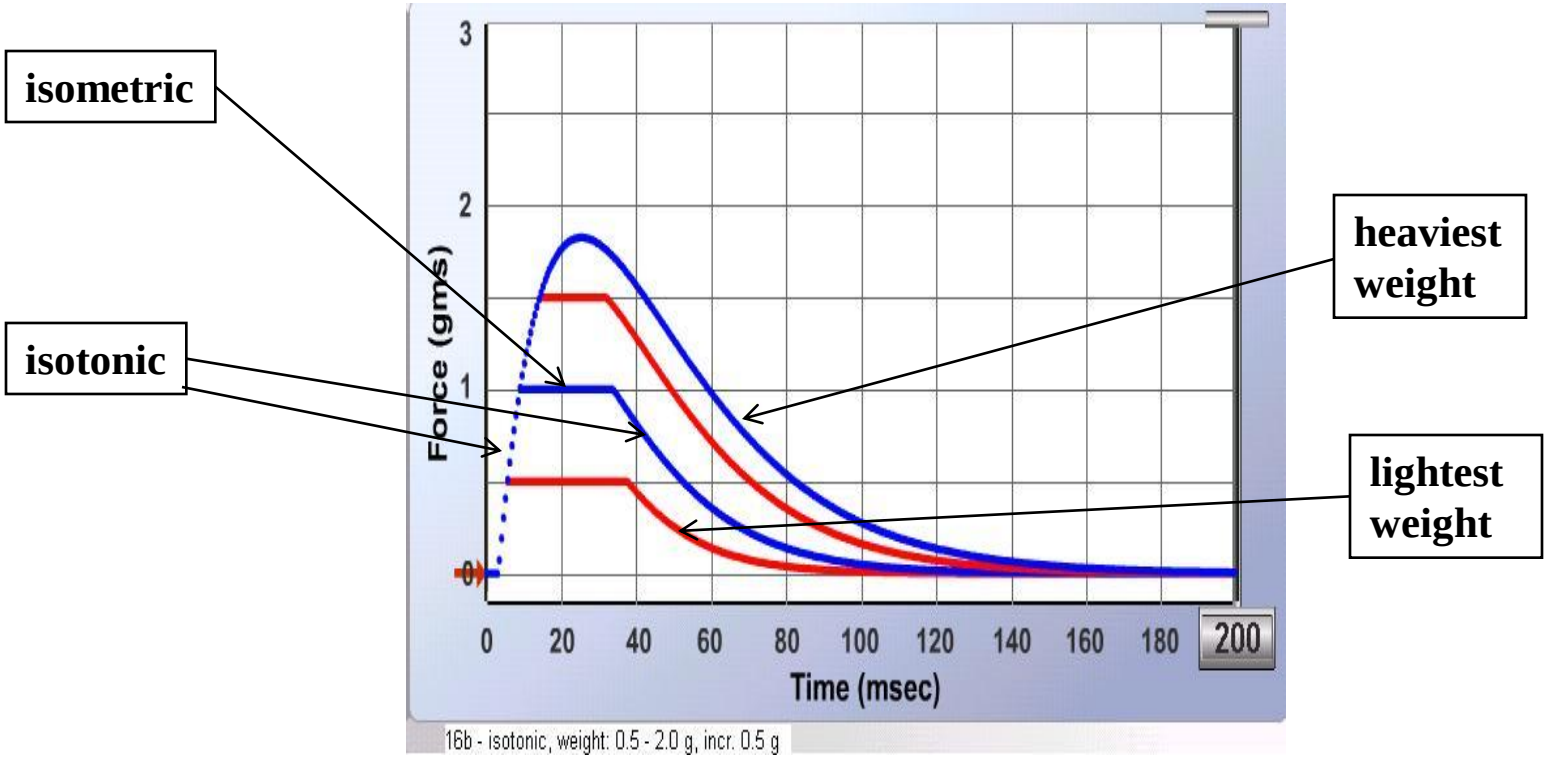
muscle contractions
→ muscle length change or not,
which affects if a load is moved or not

1) isometric contractions
- load is not moved
- muscle length - does not change

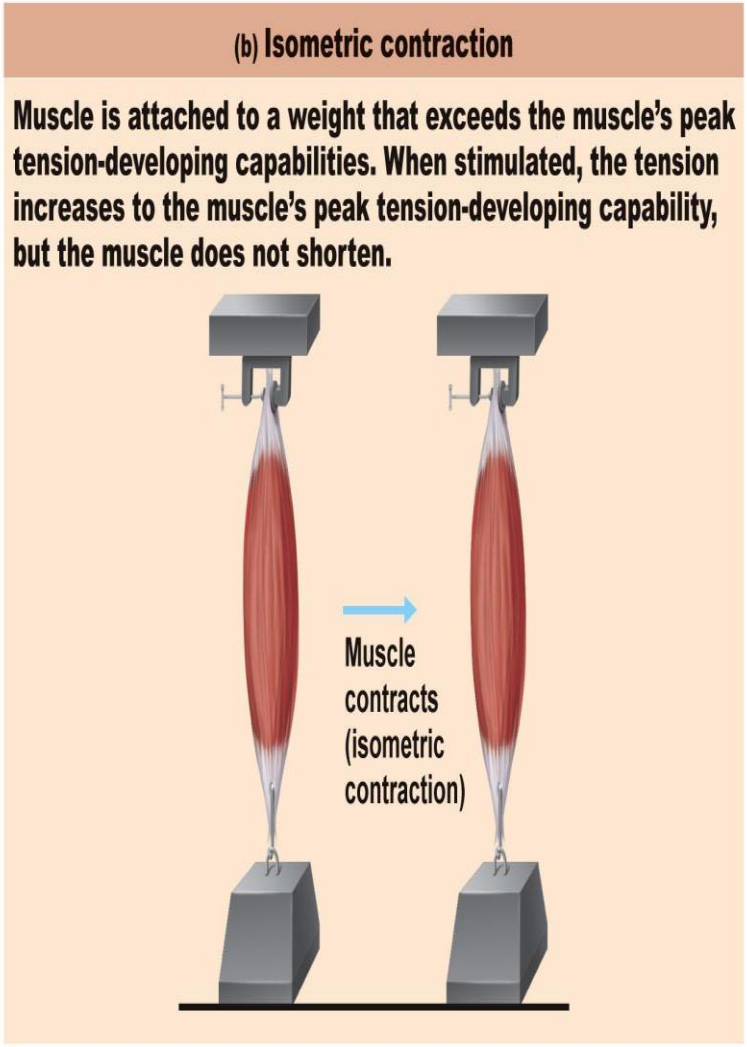
2) isotonic contractions
- load is moved
- muscle length does change
(concentric - shortens, eccentric - lengthens)

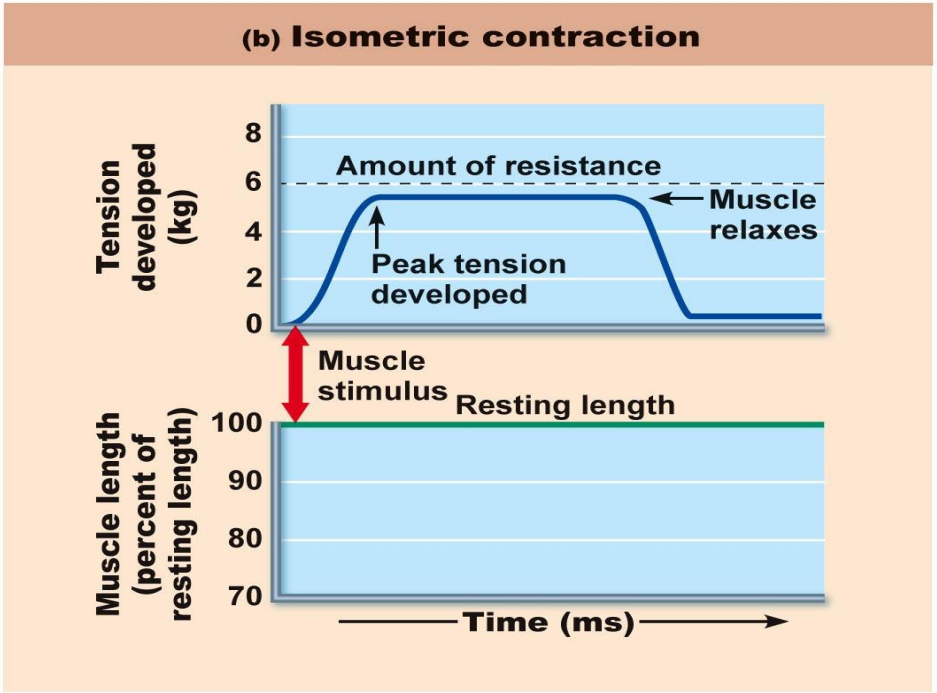
Isotonic & Isometric Combined

a) 3 phases: isotonic → isometric → isotonic
b) isotonic: lift & put down weight
c) isometric: hold weight
- longest time with the lightest weight
- moment only with heaviest weight



Isometric Contractions





force does not match load
length remains the same
load is not moved; no work

Muscle Length Δ

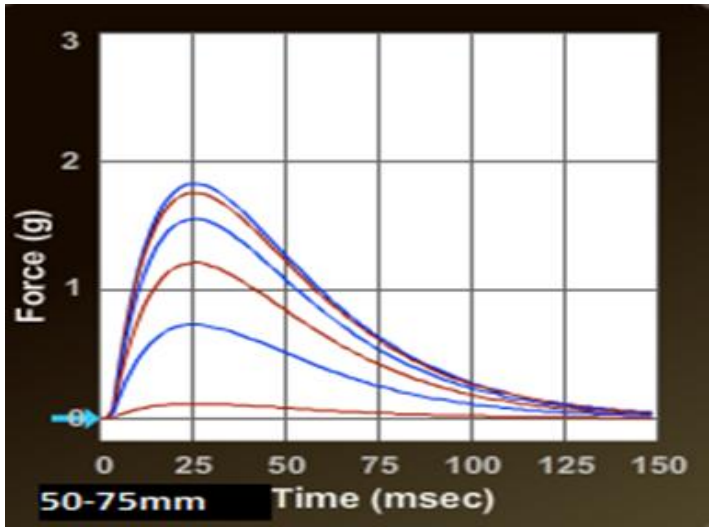
- isometric contractions*

a) shortened to natural muscle length: force increases

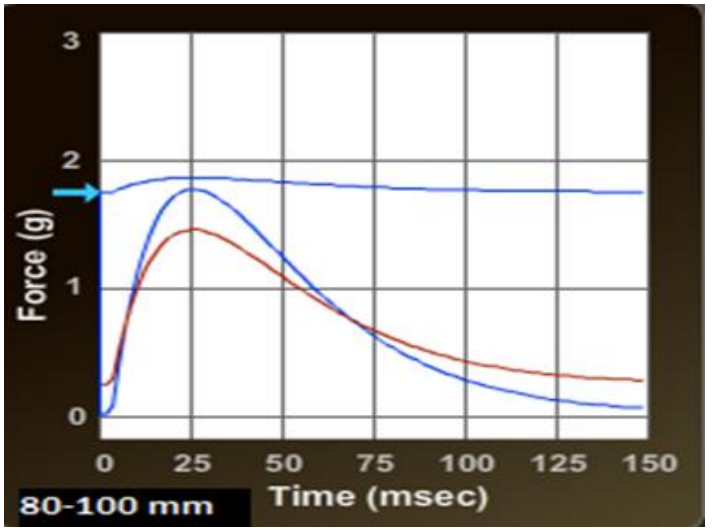
b) natural to stretched muscle length: force decreases

***** work is not performed**

50–75 mm: force increase

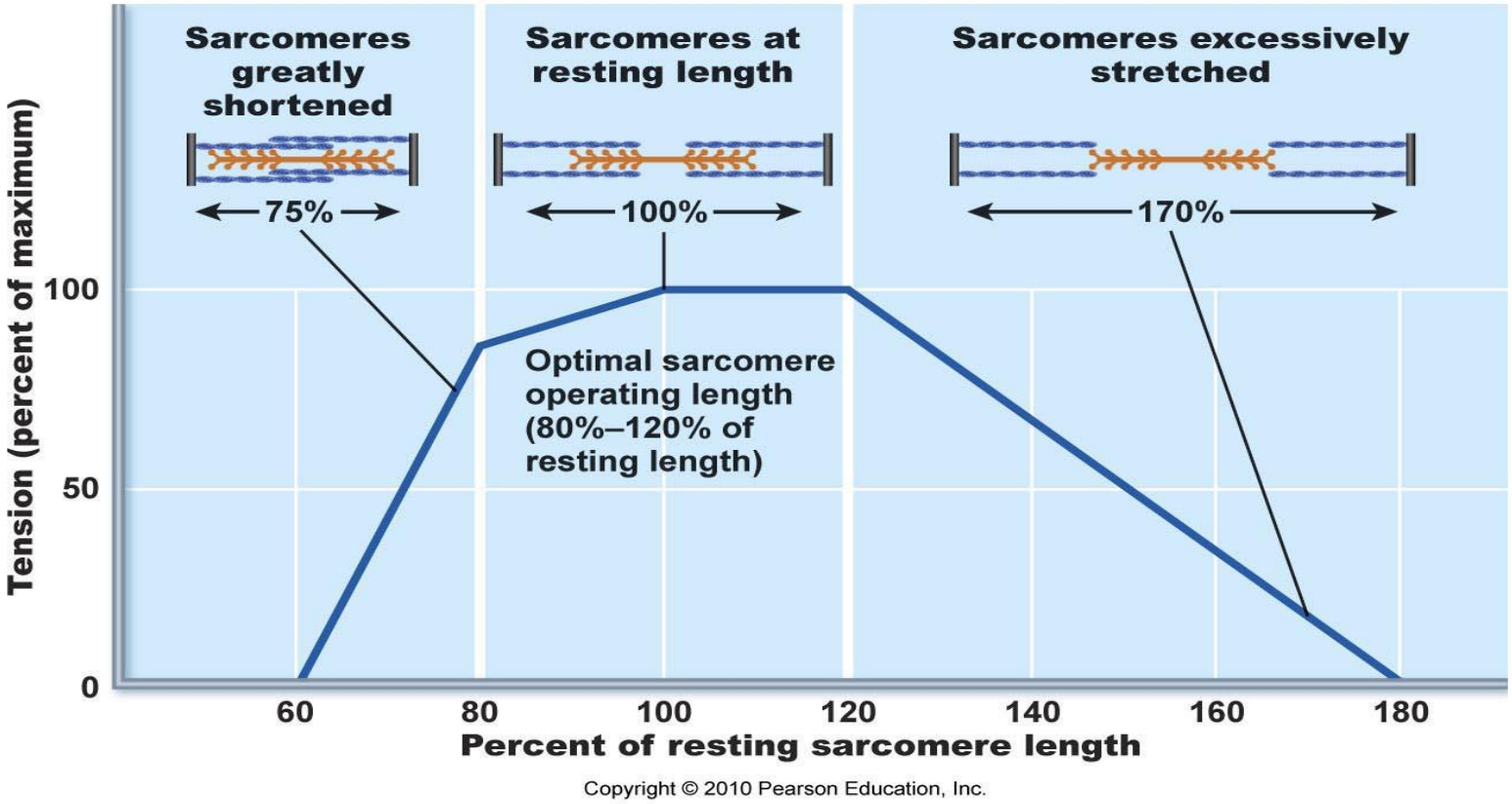


80–100 mm: force decrease



Length - Tension (1)

relaxed (resting length) muscle: most force



Length - Tension (2)

a) cramped muscle (shortened length, 60-80%)
→ prod 0-80% force
eg handcuffs, arthritis

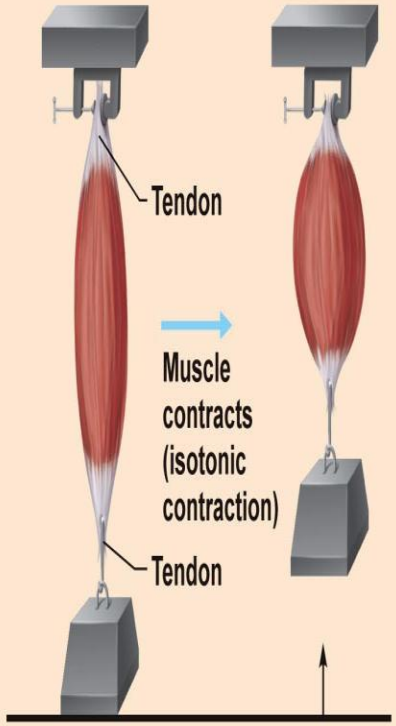
b) relaxed muscle (natural length, 80-120%)
→ prod 80-100% force
eg stretch before workout

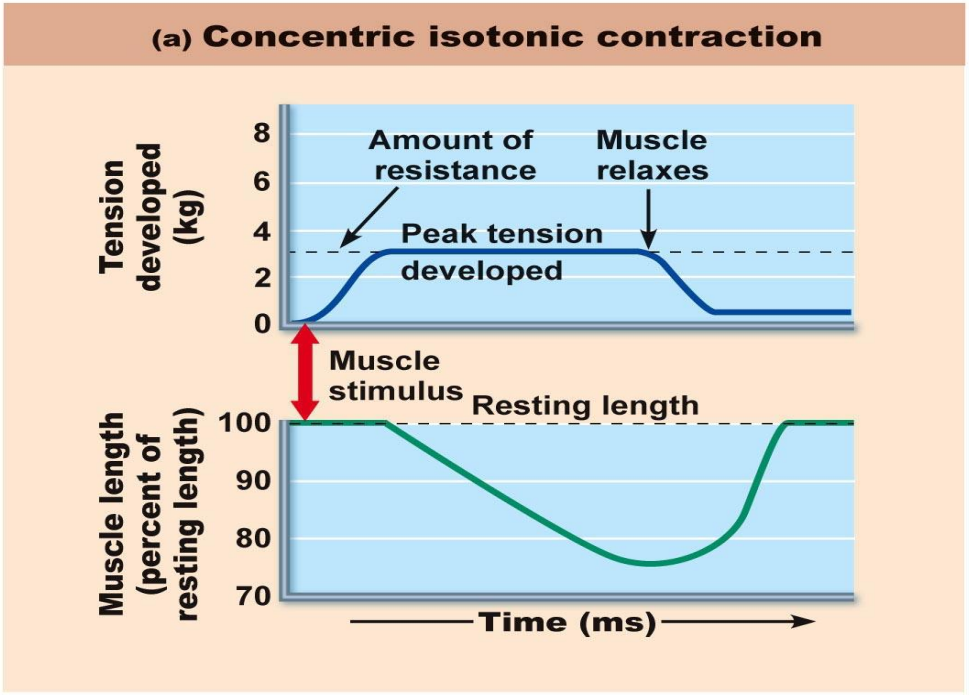
c) stretched muscle (pulled length, 120-180%)
→ prod 100-0% force
eg strait jacket

Isotonic Contractions

(a) Concentric isotonic contraction

On stimulation, muscle develops enough tension (force) to lift the load (weight). Once the resistance is overcome, the muscle shortens, and the tension remains constant for the rest of the contraction.





force matches the load
length changes (shortens)
load is moved; work occurs

Muscle Length Changes

Isotonic contraction: muscle length changes

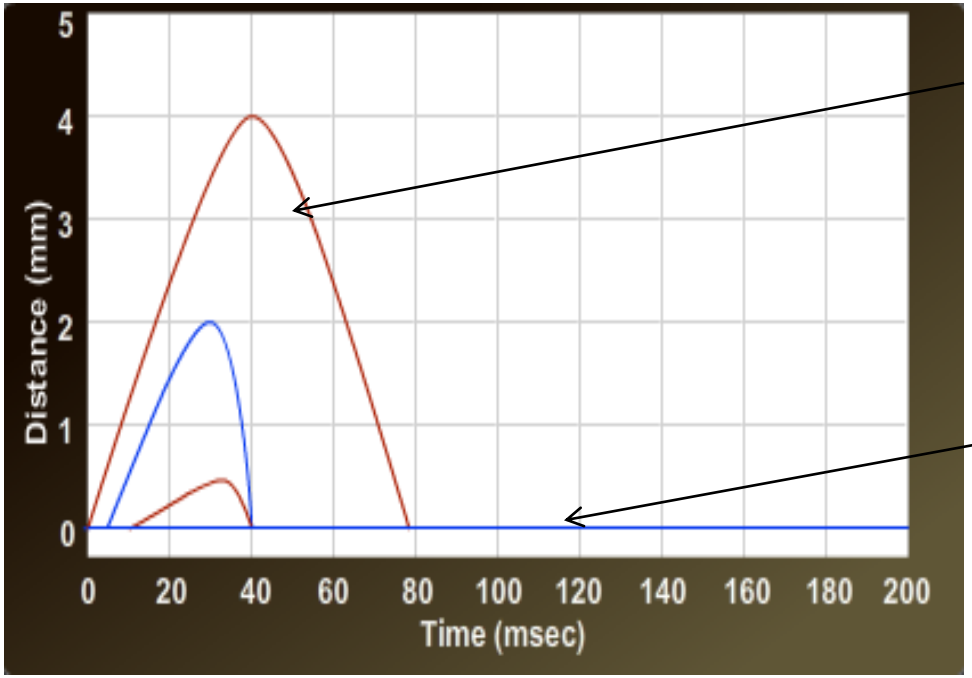
a) concentric changes (towards center)
- **muscles shorten during contraction**
- **eg lift baby up (biceps shorten)**

b) eccentric changes (away from center)
- **muscles lengthen during contraction**
- **eg put baby down (biceps lengthen)**

Isometric contraction: no muscle length change
- **muscle length remains the same length**
- **eg keep holding baby (biceps remain same length)**

Isotonic - Work

work is performed: load is moved a distance
a) lightest weight pickup – ↑ distance & time
b) heaviest weight pickup – ↓ " & "

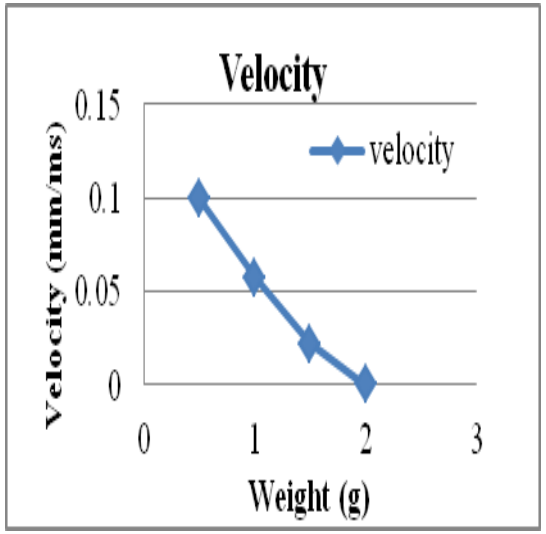


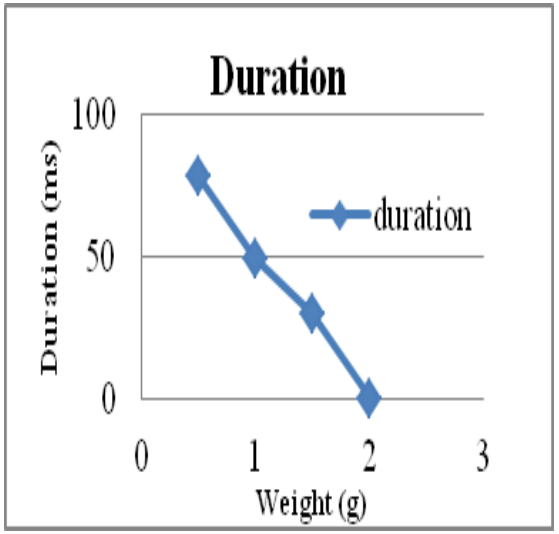
lightest weight

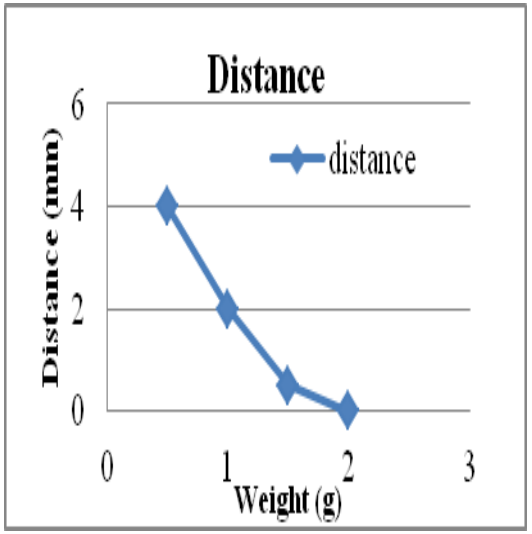
heaviest weight

Isotonic Only - 3 factprs

a) lightest weight pickup – fastest speed, ↑ distance & time
b) heaviest weight pickup – slowest " , ↓ " & "







Isotonic vs Isometric

Feature	Isotonic	Isometric .
1) force gen.	yes	yes
2) changes in	length	force
3) work occur	yes	no
4) muscle dev.	strength & flex.	strength & mass
5) activities	aerobics	body bldg/yoga

Muscle Contraction Factors

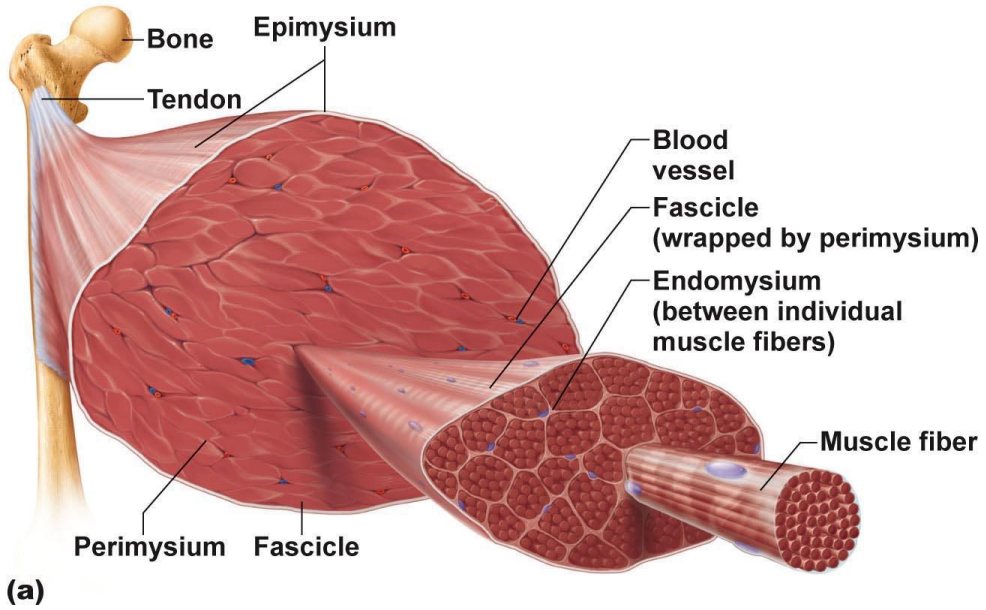
1) force/tension (contractile force)

- **a) # muscle fibers stimulated**
- **b) size of muscle fibers stimulated**
- **c) frequency of stimulation**
- **d) degree of muscle stretch**
  - **- length-tension relationship**
  - **- isometric contractions**

2 & 3) velocity, duration

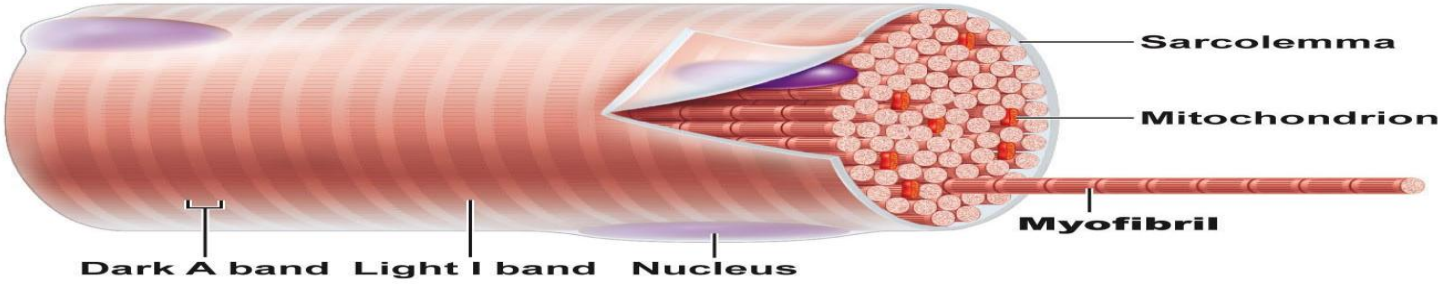
- **e) muscle fiber type**
- **f) load – isotonic contractions**
- **g) recruitment**

Skel. Muscle Levels



5 levels:

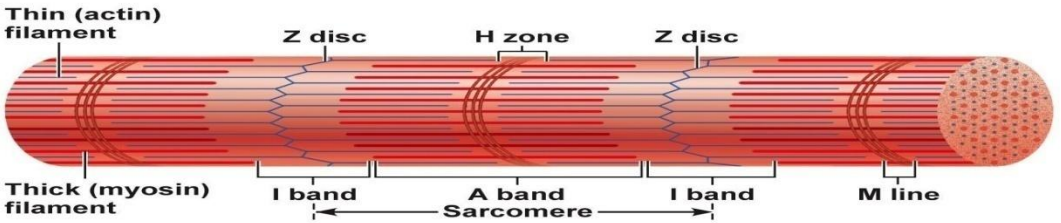
1) **muscle**
2) **fasiculus**
3) **fiber**
4) **myofibril (sarcomere)**
5) **myo-filament**



(b) Diagram of **part of a muscle fiber** showing the myofibrils. One **myofibril** is extended afrom the cut end of the fiber.

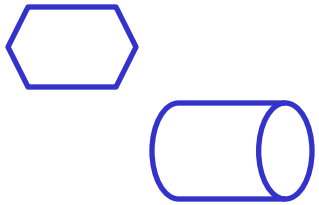
Sarcomere

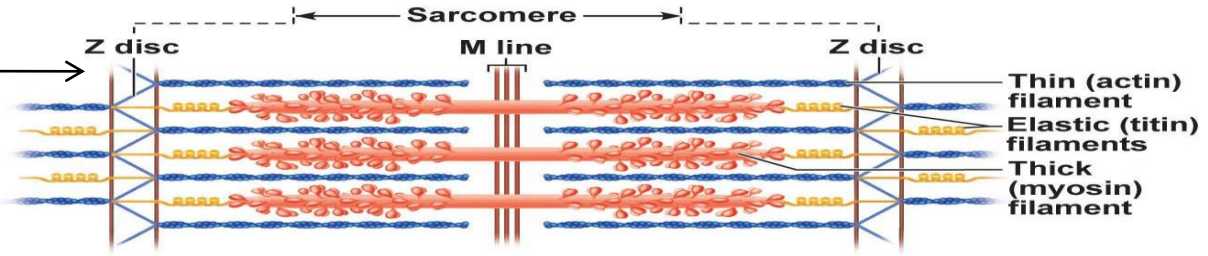
myofibril



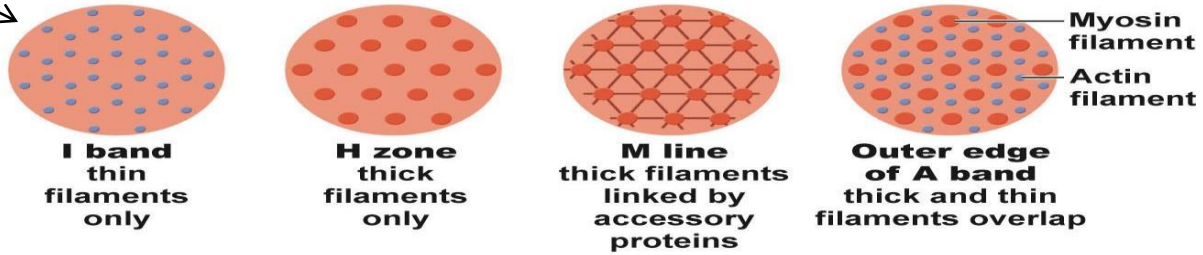
(c) Small part of one **myofibril enlarged to show the myofilaments** responsible for the banding pattern. Each **sarcomere** extends from one Z disc to the next.

sarcomere
note: hexagon shape





(d) **Enlargement of one sarcomere** (sectioned lengthwise). Notice the myosin heads on the thick filaments.



(e) Cross-sectional view of a sarcomere cut through in different locations.

Parts of the Sarcomere

a) components:

1) 2 bands: light (I) & dark (A) bands
2) 3 filaments: myosin, actin, titin
3) zone: H zone
4) line: Z line/disc, M line

b) striations:

1) dark: A band (myosin, H zone, part of actin)
2) light: I band (part of actin, Z line)

c) hexagonal shape: 1 thick to 6 thin filaments

d) zig-zag fit of indiv. sarcomeres

e) contraction phases:

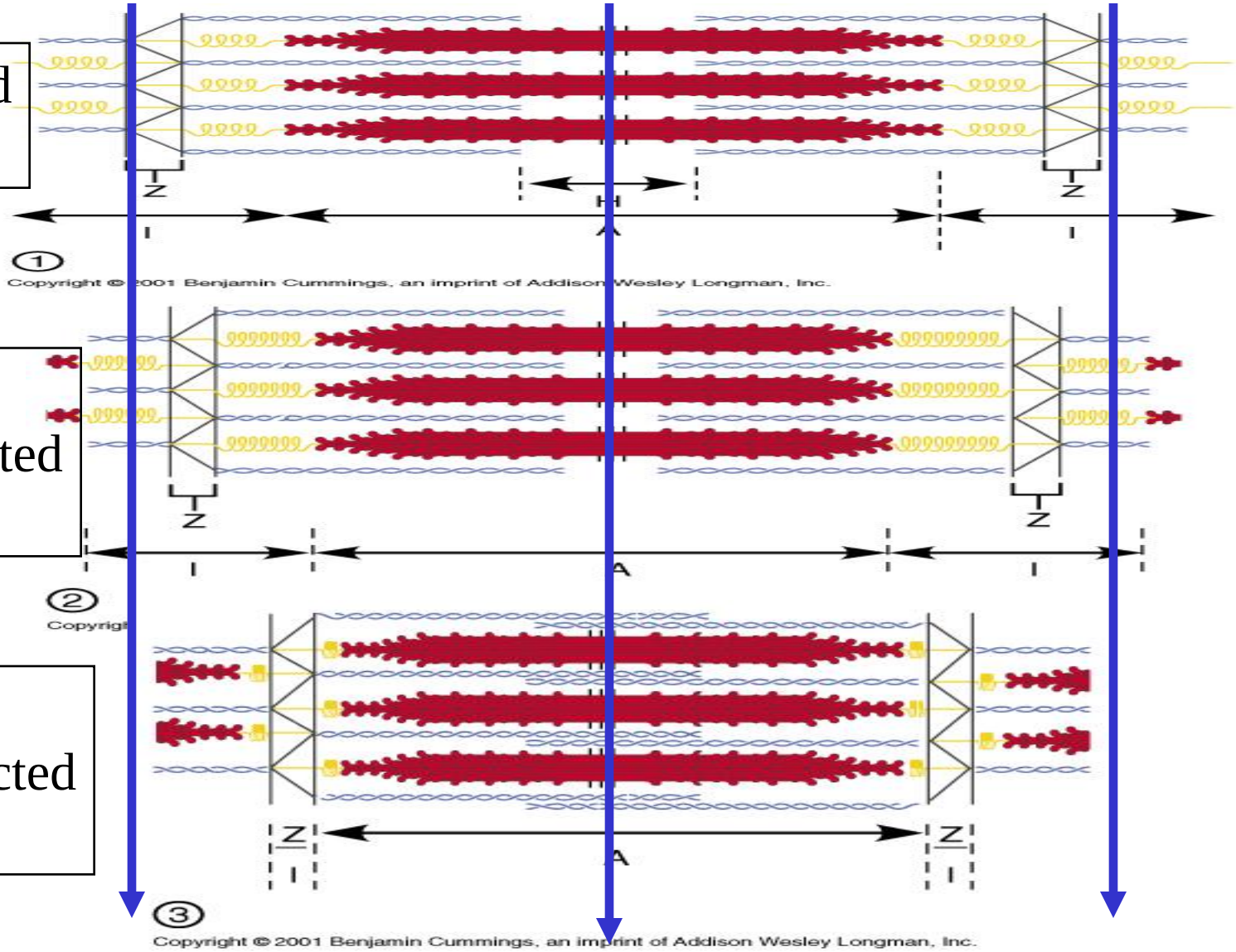
- relaxed, partially contracted, fully contracted

Sarcomere Contractions (2)

relaxed phase

partly contracted phase

fully contracted phase



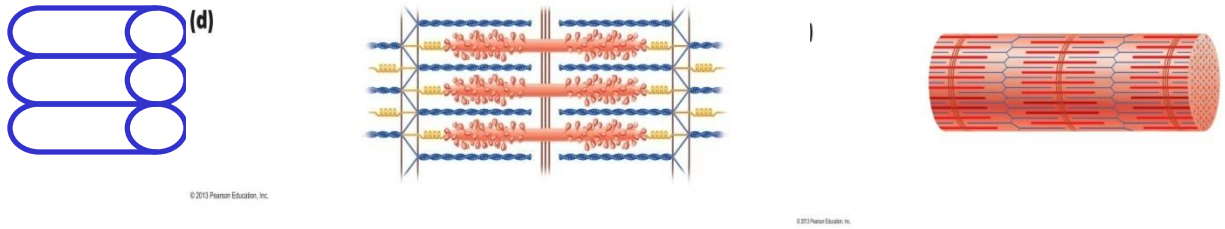
Sarcomere Contraction (3)

Phase	Dark (A) band			Light (I) band		
	myos.	actin	H zone	actin	Z line	titin
1) relaxed phase	same	apart	open	visible	with space	relaxed, long
2) partly contracted phase	same	closer	part closed	less visible	less space	tighter, shorter
3) fully contracted phase	same	over-lap	over-closed	not visible	little space	tight, short

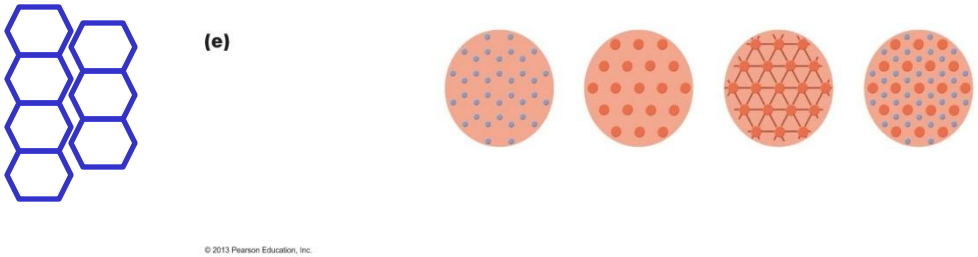
Sarcomere Hexagon (1)

hexagon shape: 6 actin myo-filaments
- zigzag fit of indiv. sarcomeres

length wise view



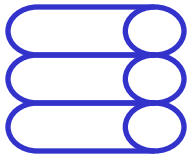
cross-section view



Sarcomere Hexagon (2)

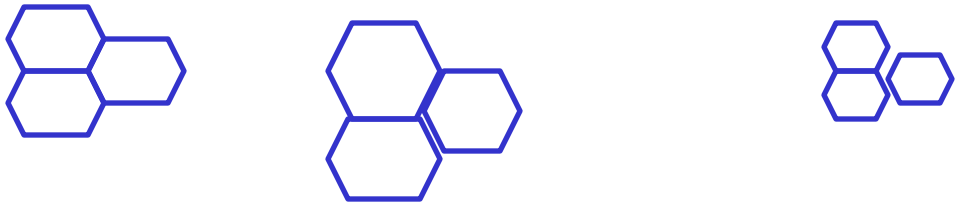
hexagon shape: 6 actin myo-filaments
- zigzag fit of indiv. sarcomeres

length wise view



concentric **eccentric**

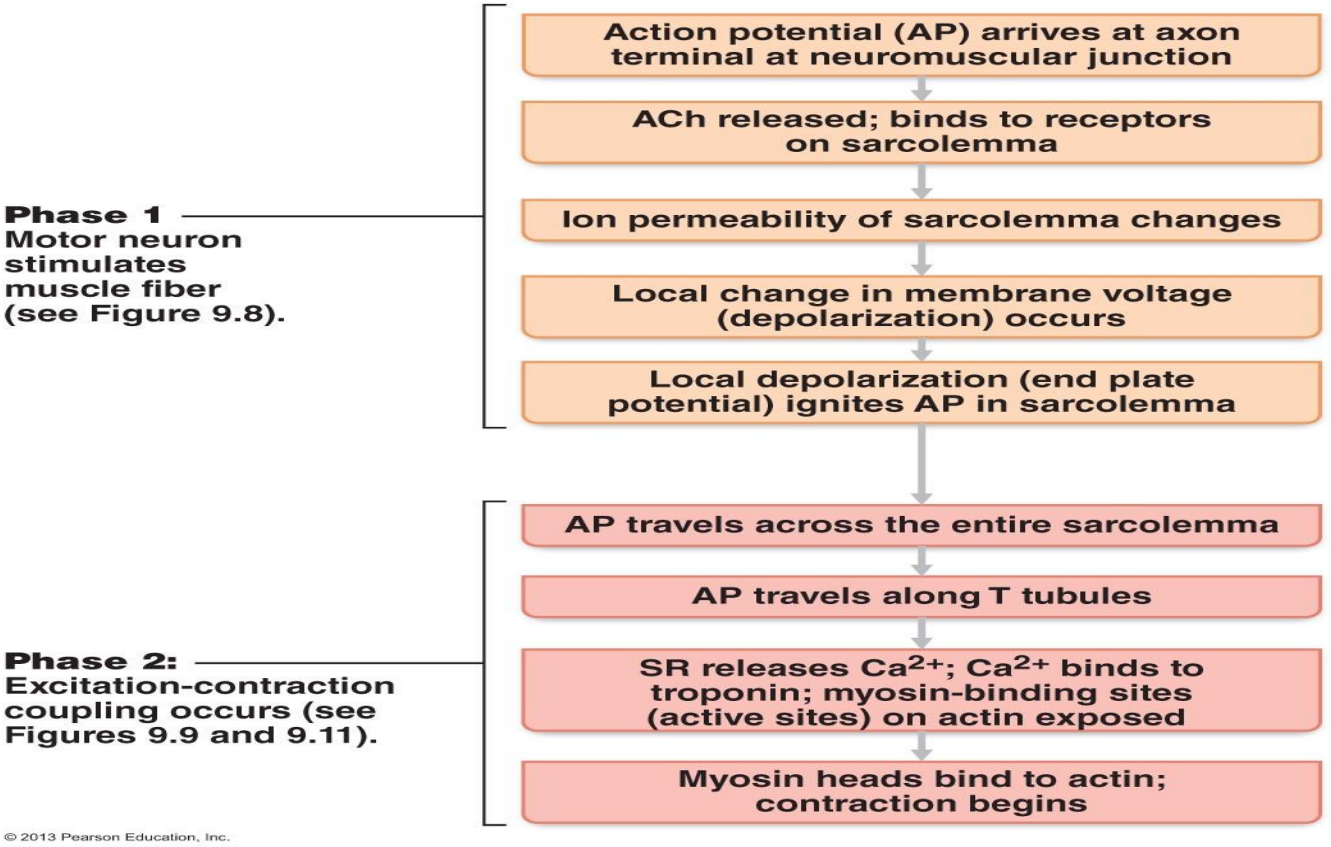
cross-section view



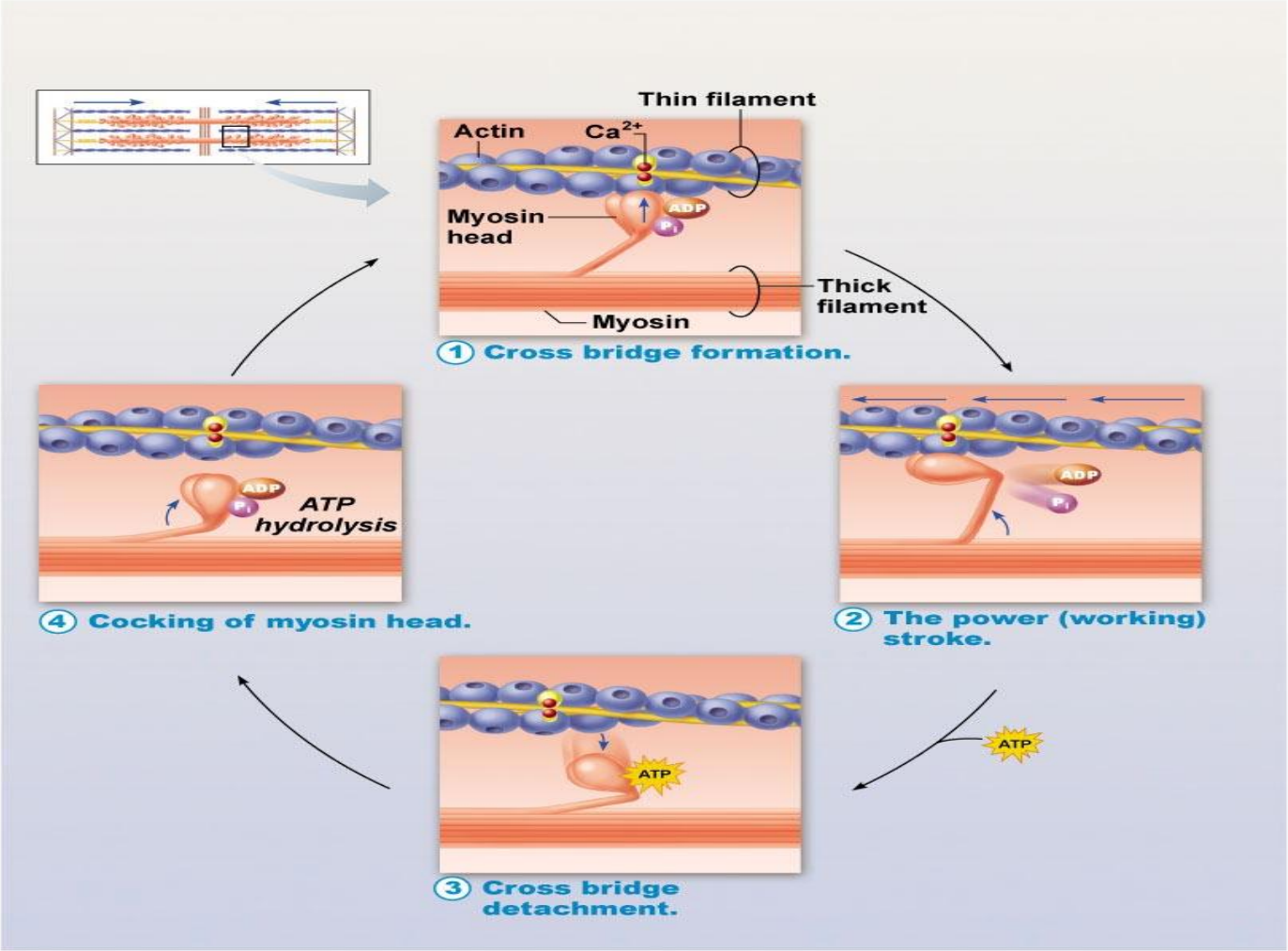
shorter, thicker sarcomere **longer, thinner sarcomere**

Nerve-Muscle Interface

Phase 1: neural excitation
Phase 2: excitation-contraction
(neural excitation -> muscle contraction)



Cross-Bridge Cycle (1)



Cross-Bridge Cycle (2)

Action	Actin Position	Myosin Head	Sarcomere Size * .
1) attach	stationary	to troponin	original
2) working stroke	a) slides to center	pulls actin to center	shorten, thicker
	b) slides from center	pulls actin from center	lengthen, thinner
3) detach	a) slides from center	pulls actin from center	lengthen, thinner
	b) slides to center	pulls actin to center	shorten, thicker
4) cock	stationary	to troponin	original

*note: concentric & eccentric muscles