Biological Frameworks for Engineers

ME 411 / ME 511

Biological Frameworks for Engineers

UNIVERSITY OF WASHINGTON

Class Organization

- HW5 due Friday.
- Lab 3 – Muscle Lab
  - Friday (11/14)
  - MEB 127
  - 1:30, 2:30, 3:30 sign-up
- No class on Wed 11/19

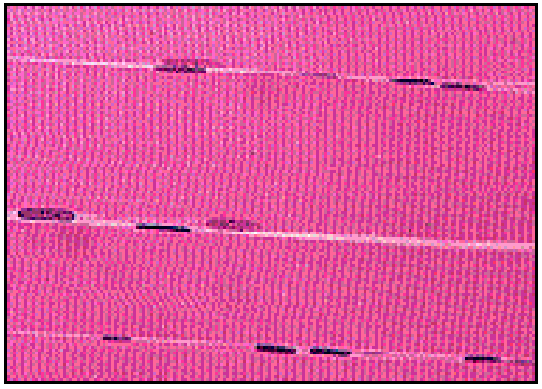
Biological Frameworks for Engineers

ME 411 / ME 511

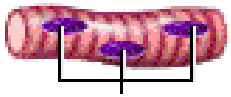
Muscle Cells to Tissues

UNIVERSITY OF WASHINGTON

Muscle Overview

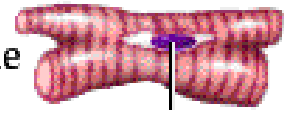


Skeletal Muscle
300 x

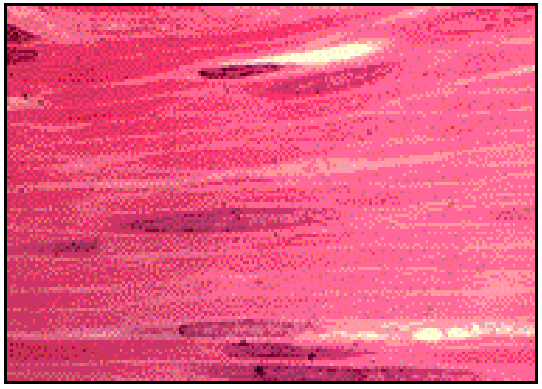


- Elongated cell
- Multiple peripheral nuclei
- Visible striations
- Voluntary

Cardiac Muscle
400 x



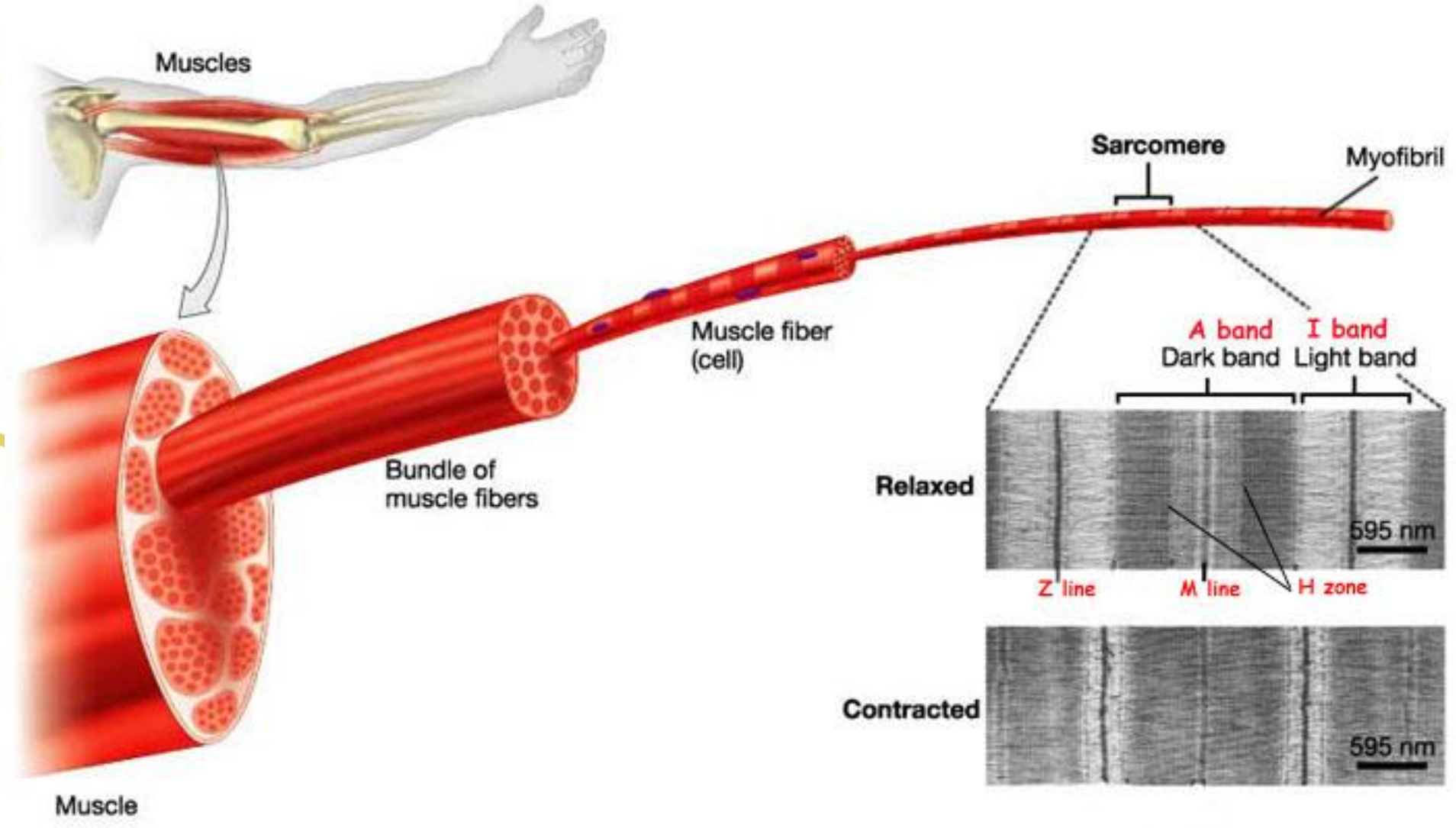
- Branching cell
- Single central nucleus
- Visible striations
- Involuntary



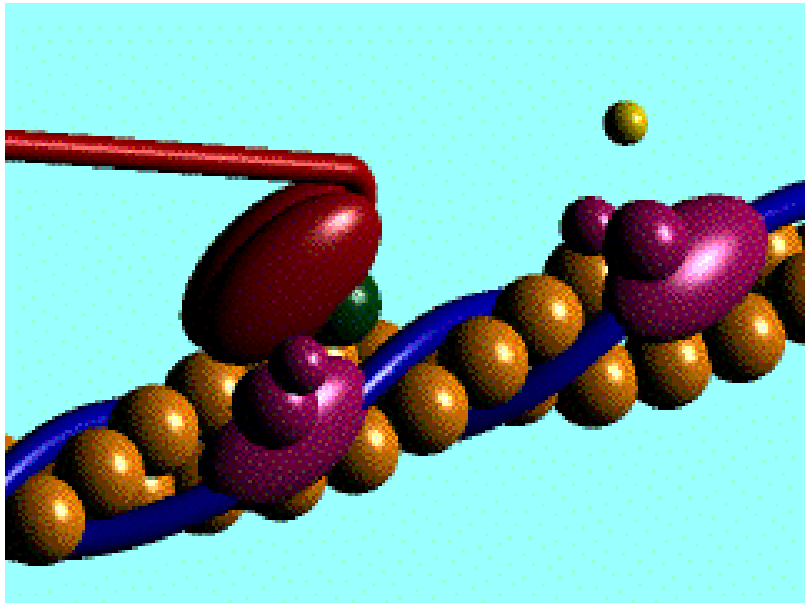
Smooth Muscle
1200 x

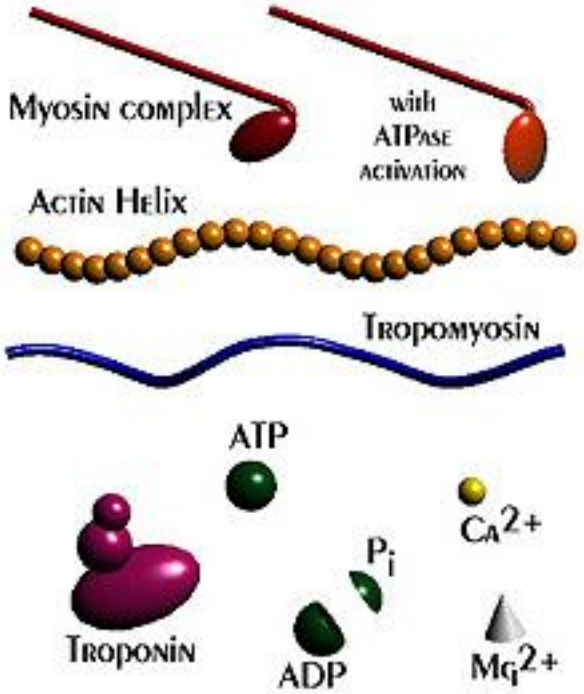
- Spindle-shaped cell
- Single central nucleus
- Lack visible striations
- Involuntary

Sarcomeres to Muscle



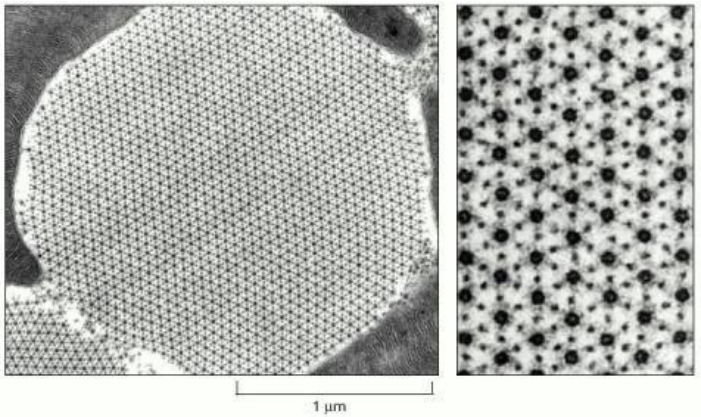
Actomyosin Contraction

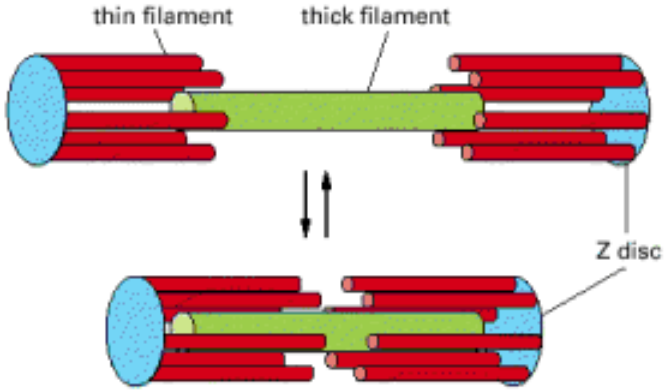


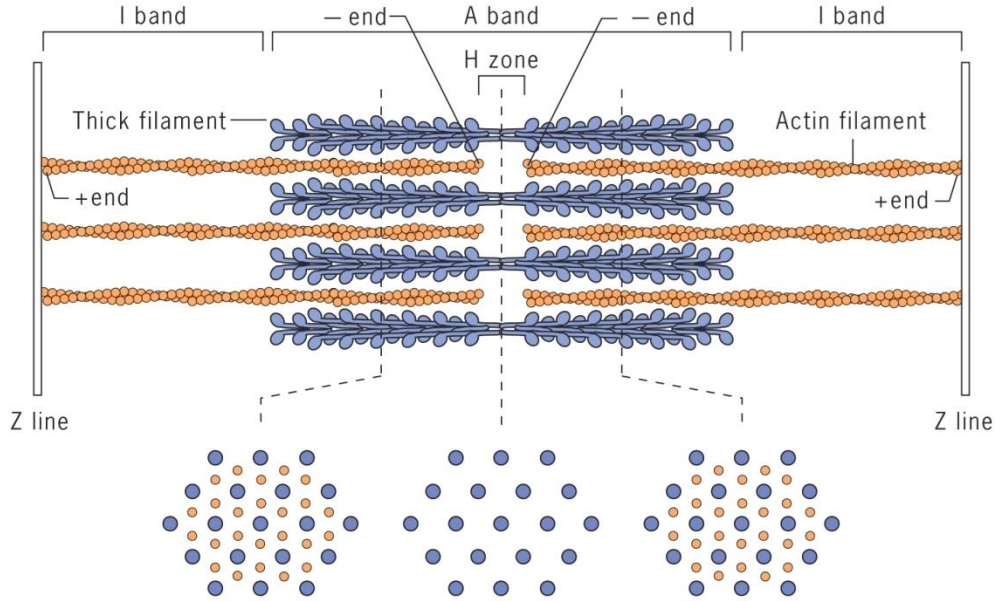


Courtesy of San Diego State University

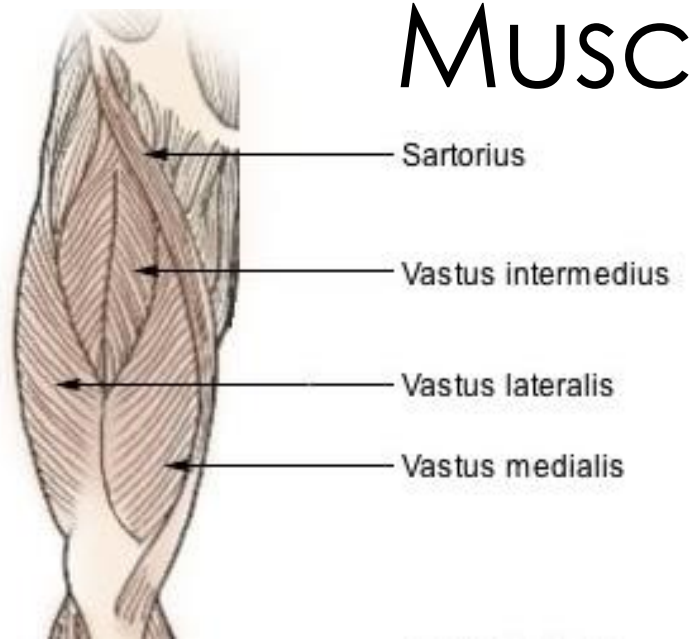
Cross-Section







Muscle Types

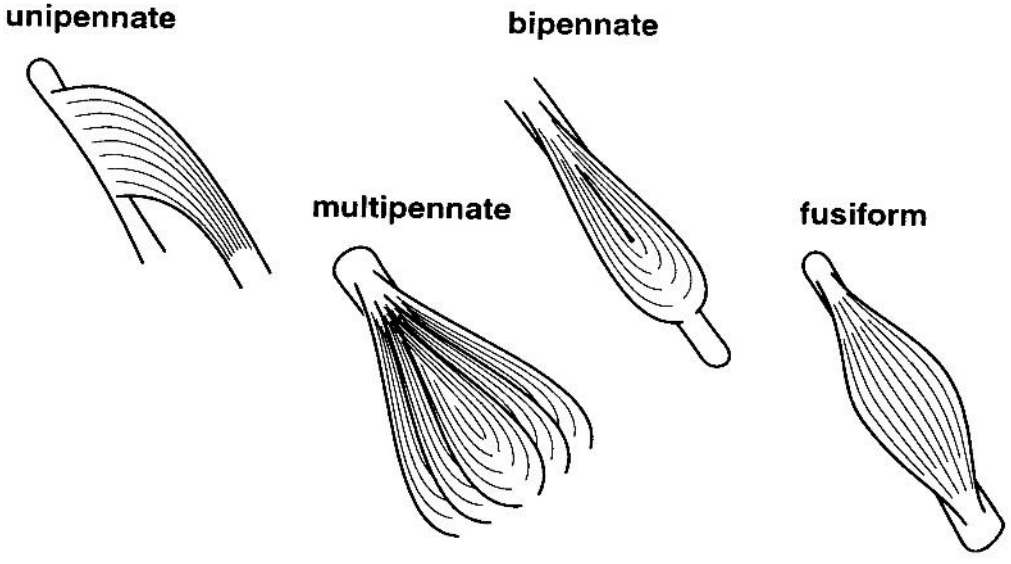


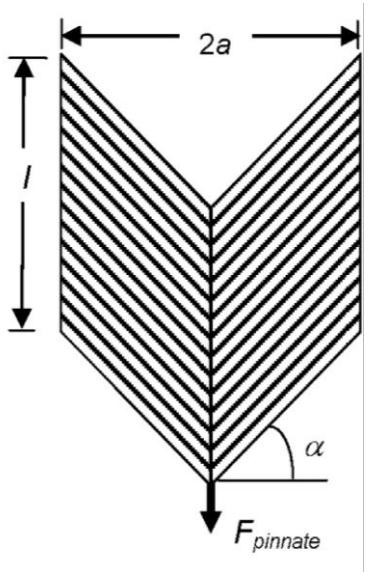
Pennate vs Fusiform Muscle

- Bipennate force larger than parallel fusiform

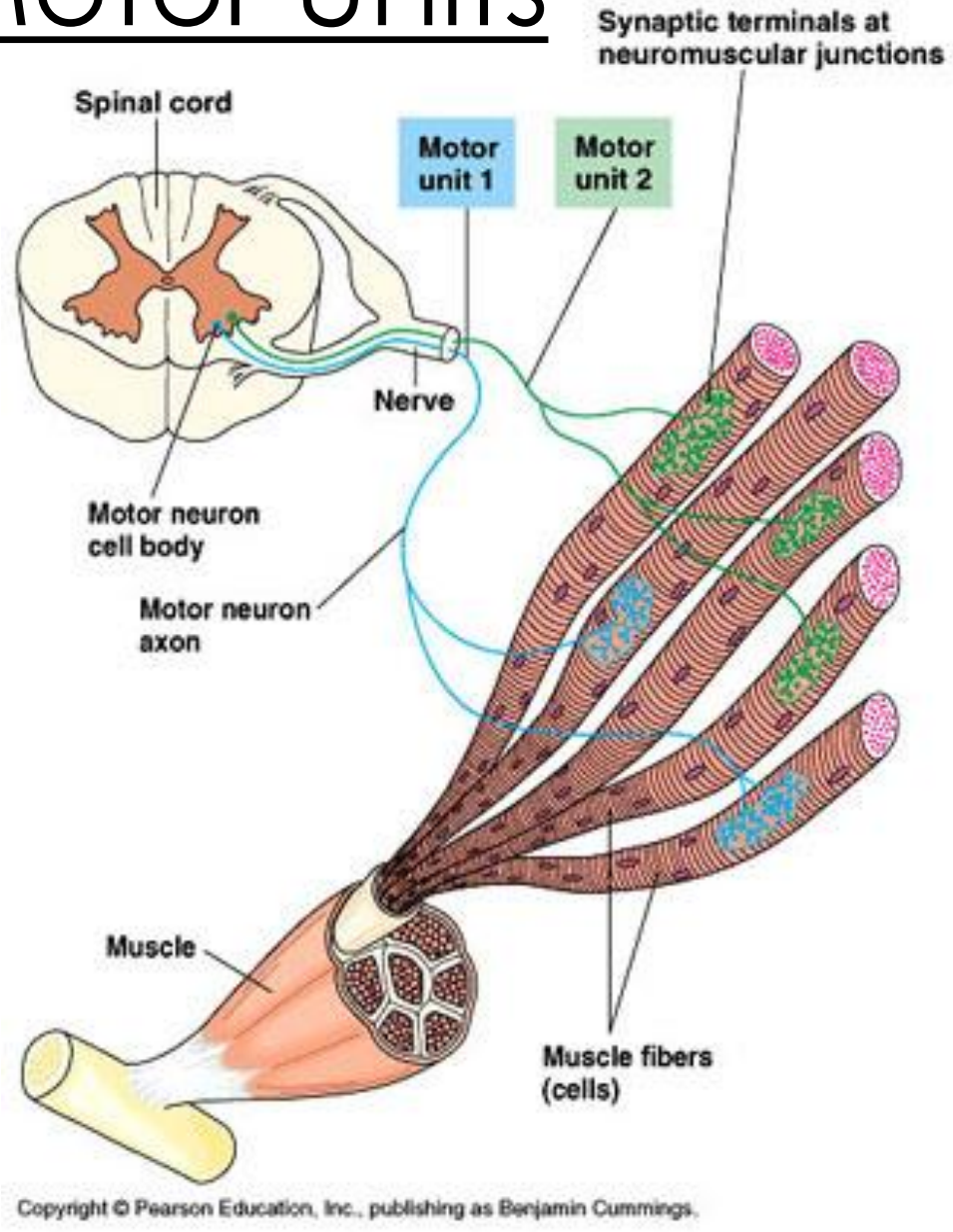
Example: Quadriceps

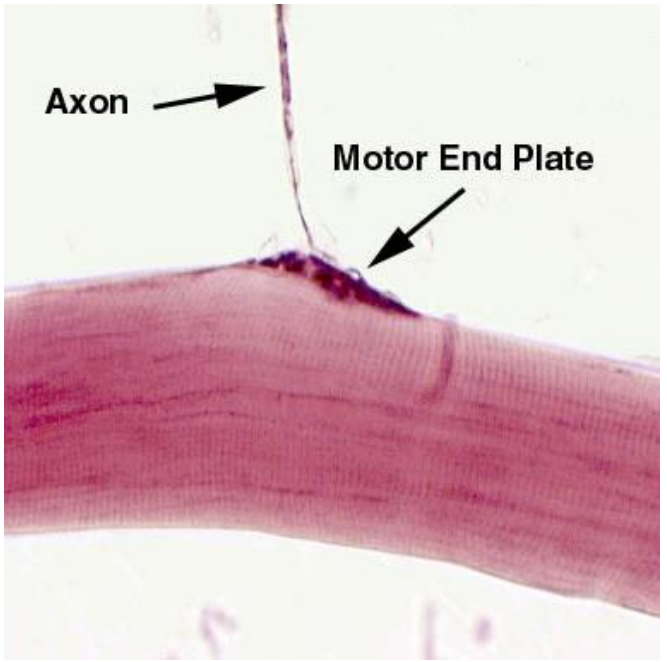
- Large set of four muscles on anterior surface of thigh
- Tendons join together (anastomose) to connect to patella (kneecap)



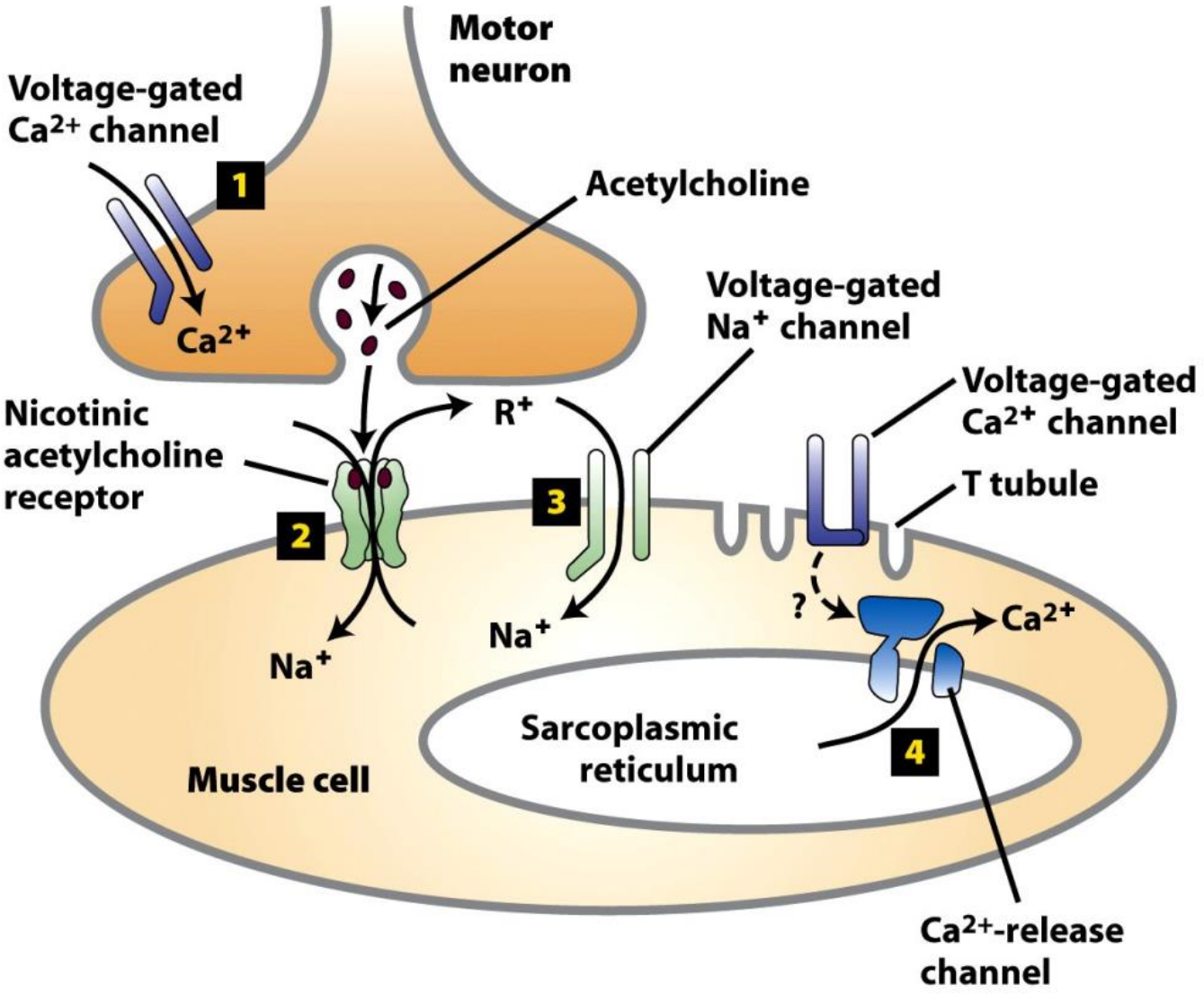


Motor Units

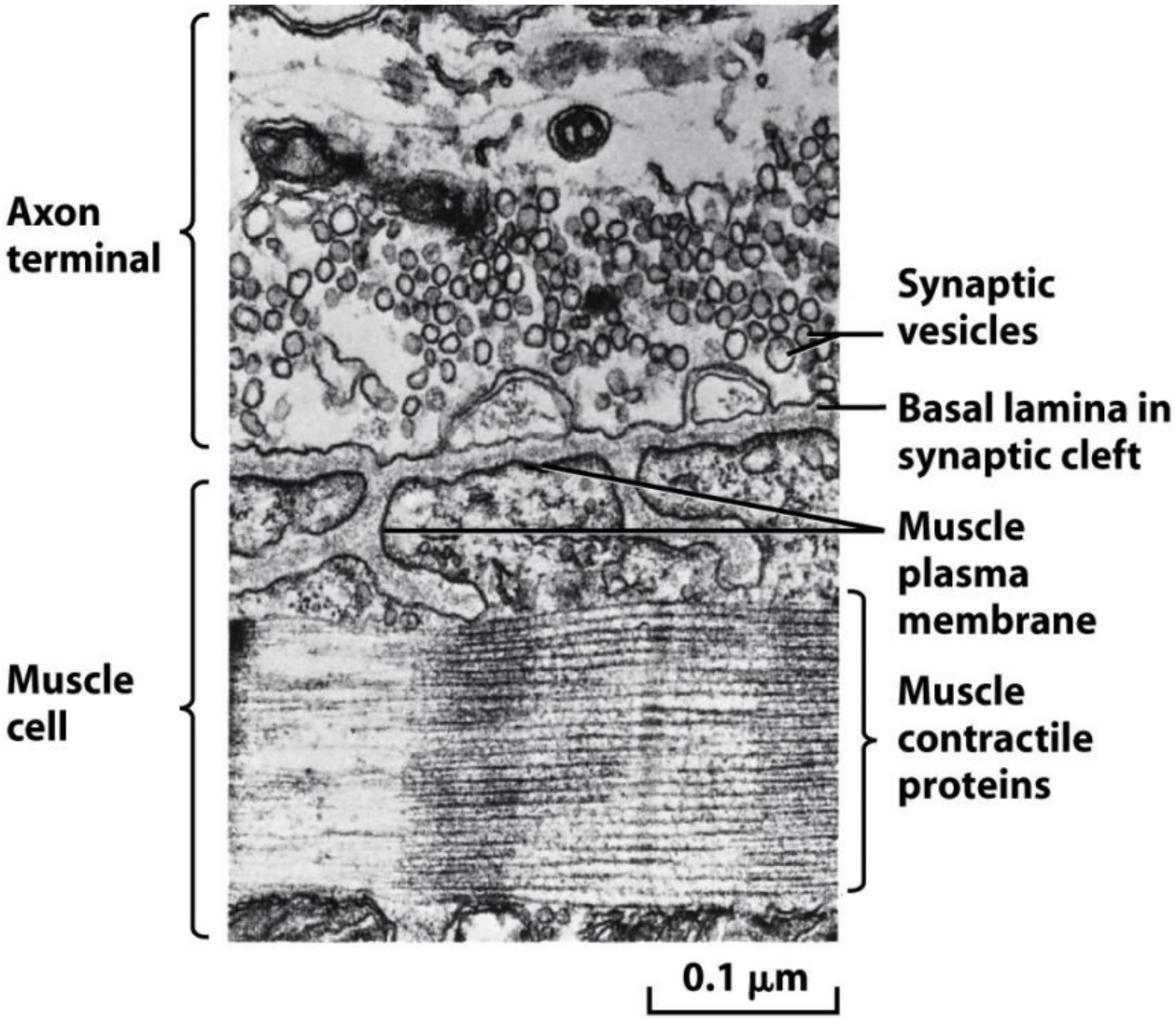

Synaptic terminals at neuromuscular junctions
Spinal cord
Motor unit 1
Motor unit 2
Nerve
Motor neuron cell body
Motor neuron axon
Muscle
Muscle fibers (cells)
Copyright © Pearson Education, Inc., publishing as Benjamin Cummings.


Axon
Motor End Plate

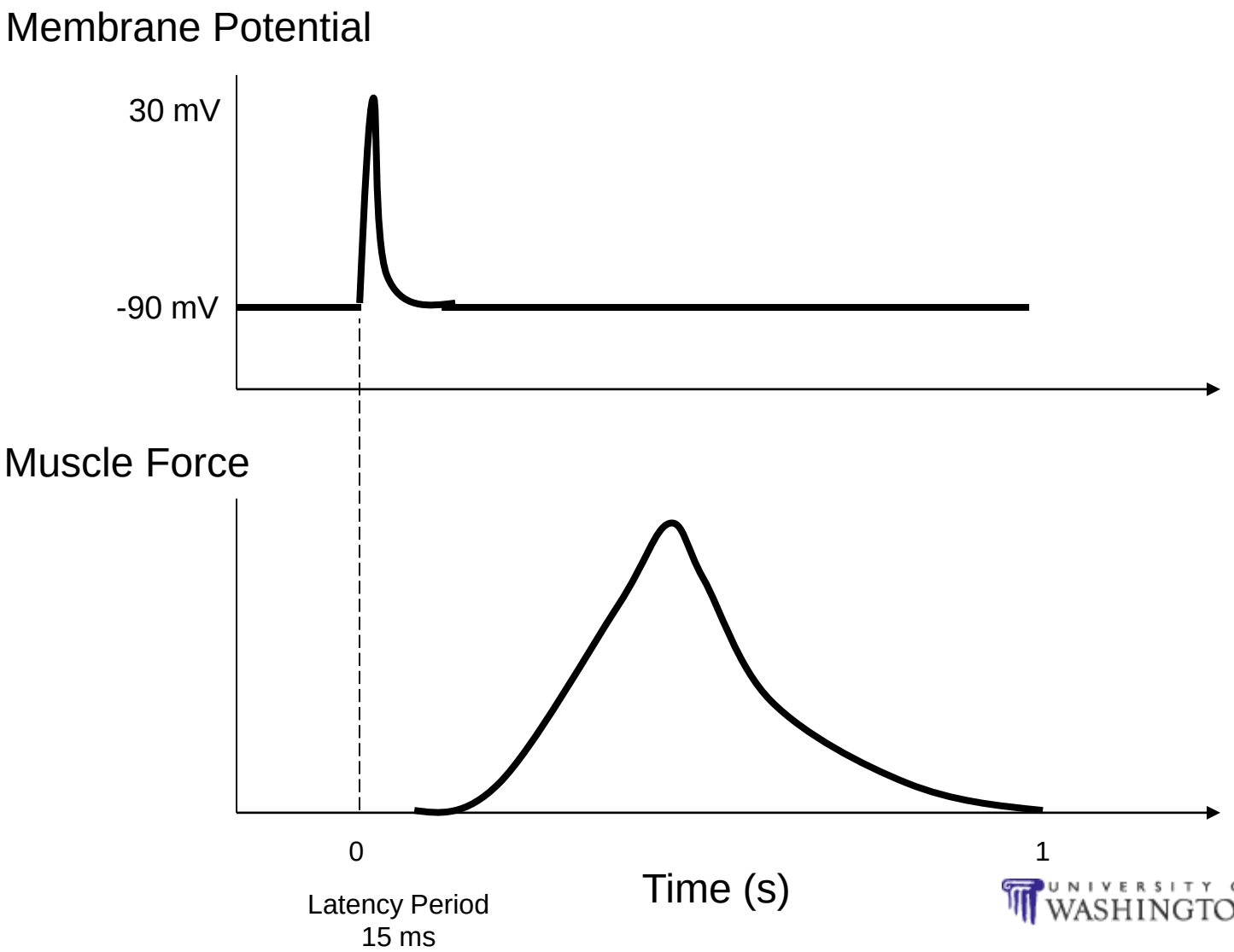
Neuromuscular Junction



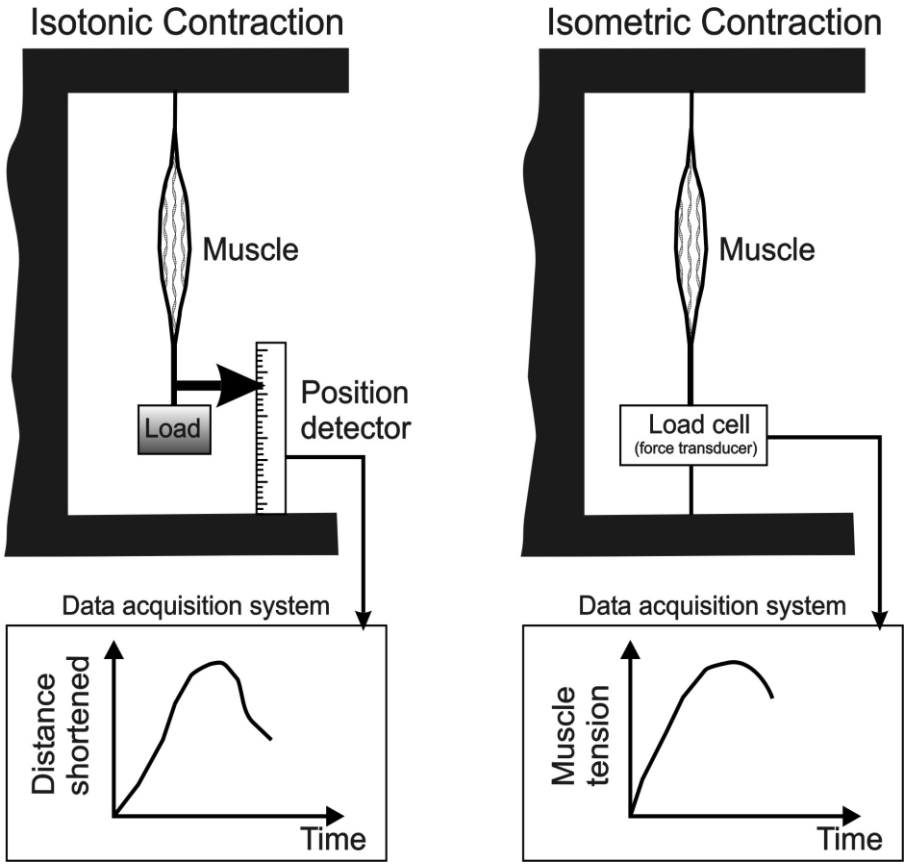
Neuromuscular Junction

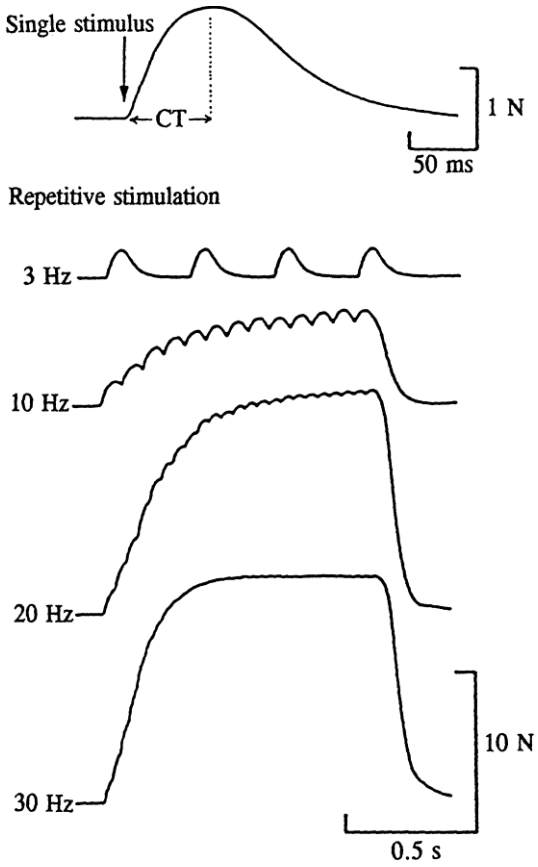


Twitch

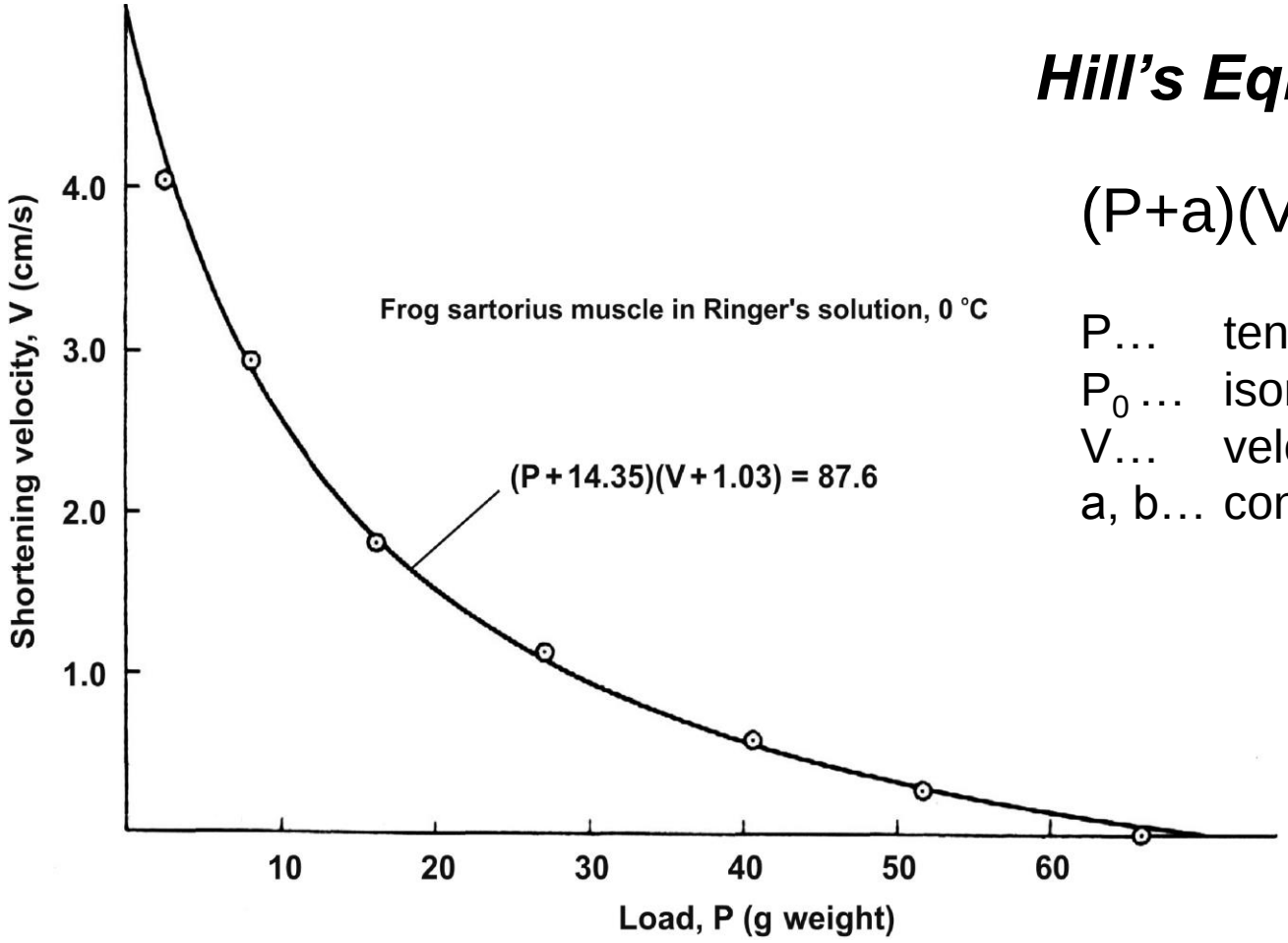

Membrane Potential
30 mV
-90 mV
Muscle Force
0
1
Time (s)
Latency Period
15 ms

Ex Vivo Frog Muscle





Force vs. Velocity

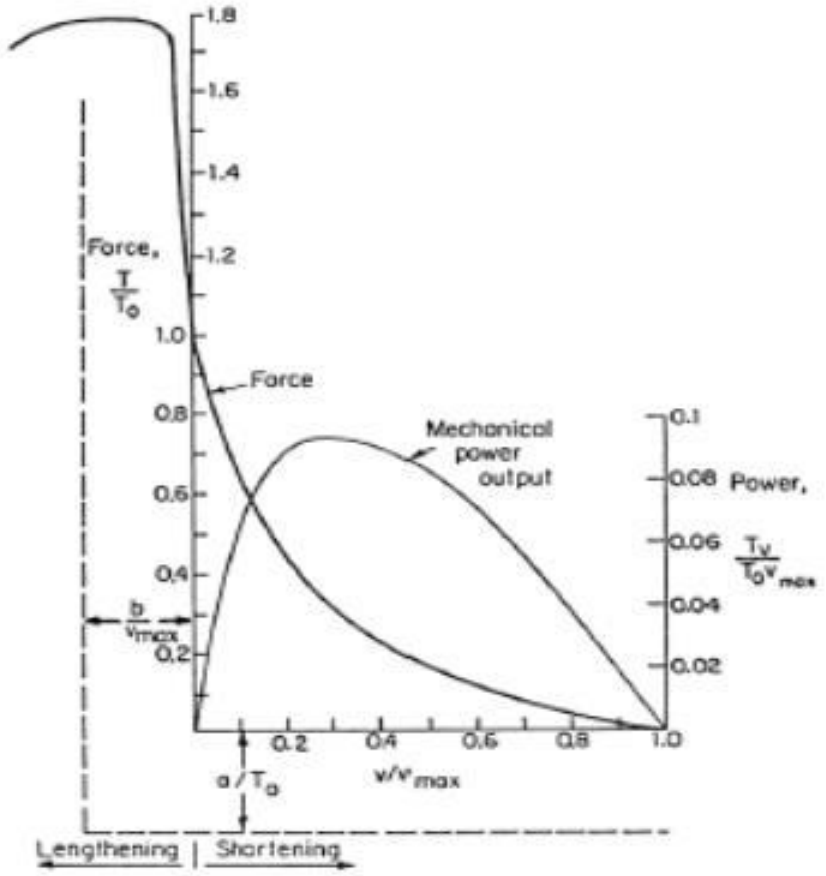


Hill's Eqn:

$$(P+a)(V+b) = (P_0+a)b$$

P… tension
P_0 … isometric tension
V… velocity
a, b… constants

Force vs. Velocity



Hill's Eqn:

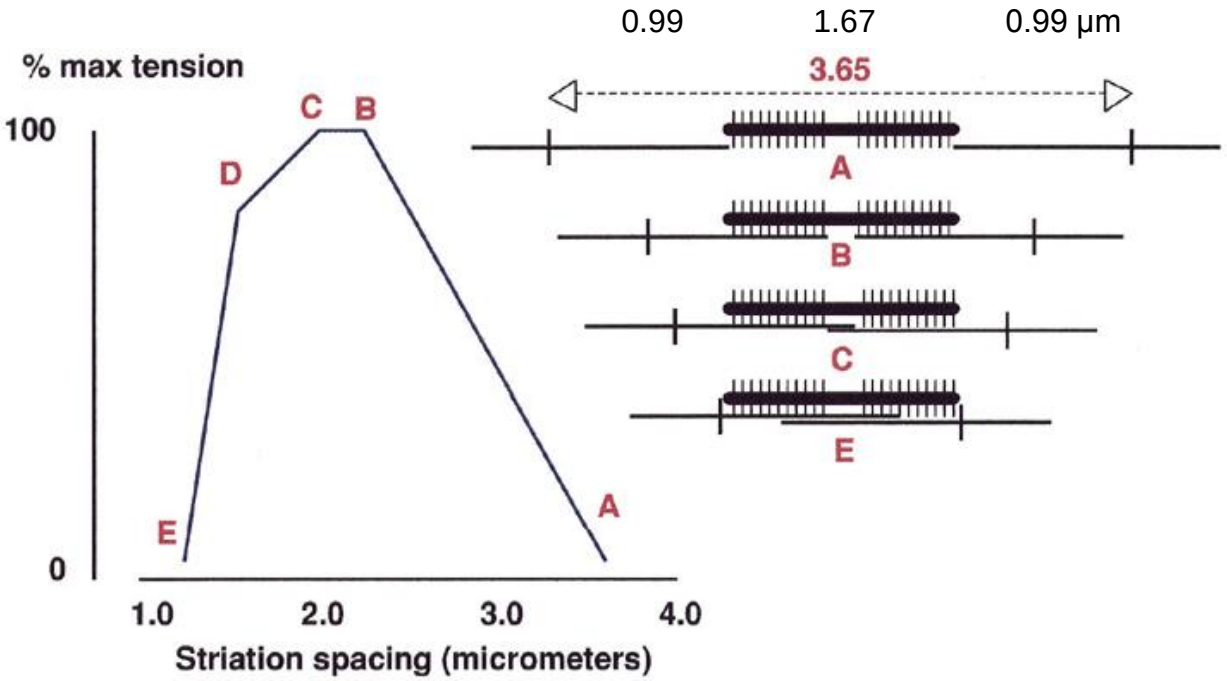
$$(T+a)(v+b) = (T_0+a)b$$

T… tension
T_0 … isometric tension
v… velocity
v_{max} …velocity against no load

$$v_{max} = b*T_0/a$$

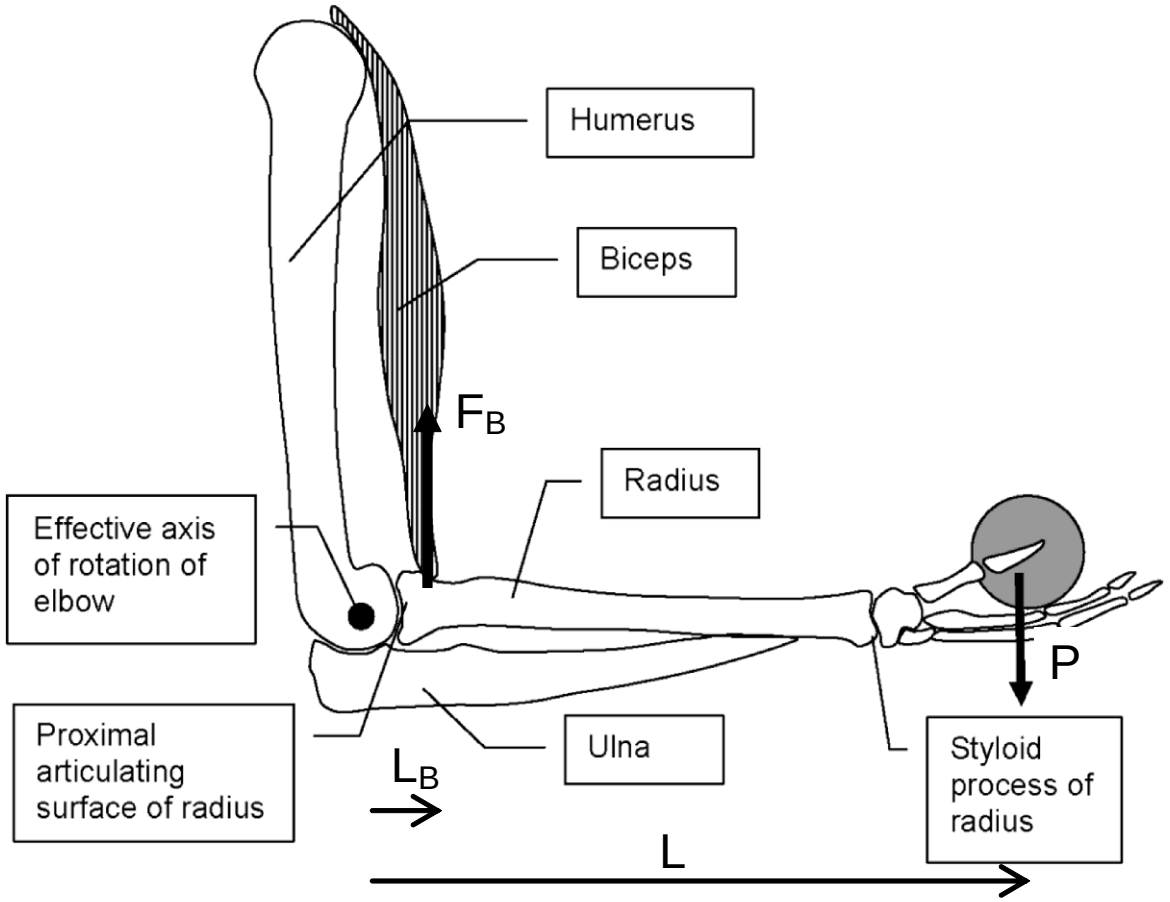
Power = T*v

Force vs. Length - Micro



Muscle Lab

Bicep Brachii



Flexion of Elbow Joint

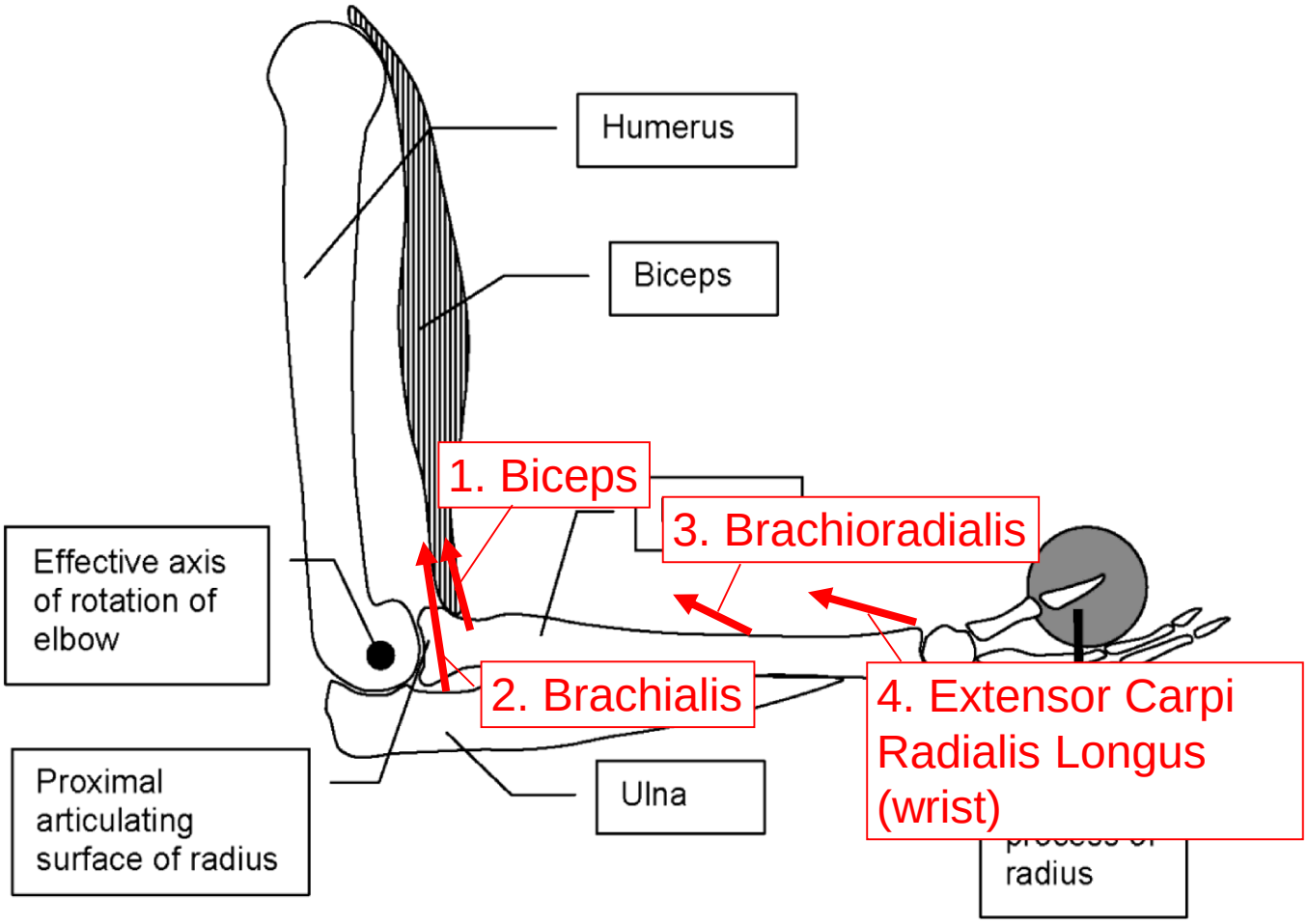


Table 8.1. Origin and insertion points and other characteristics of the four major muscles participating in elbow flexion. L_H is the distance from the effective center of rotation for the elbow to the muscle origin location on the humerus; L_F is the corresponding measurement for the insertion location on the forearm. PCSA is the physiologic cross-sectional area of the muscle (see text). $\theta = \tan^{-1}(L_H/L_F)$ is the angle that the muscle makes with respect to the horizontal when the forearm is in the position shown in Fig. 8.22. "Inserts into" refers to which bone the muscle inserts into in the forearm.

Muscle	L_H (cm)	L_F (cm)	PCSA (cm^2)	θ(°)	Inserts into
Biceps	31[a]	8	12.3	76	Radius
Brachialis	10	5	13.0	63	Ulna
Brachioradialis	8	24	2.9	18	Radius
Extensor carpi radialis longus	3	25[b]	3.6	7	Radius

A (cm^2)

[a] The biceps does not originate from the humerus. Its effective point of origin is taken at the top of the humerus.
[b] The ECRL inserts into the wrist; its effective insertion point is taken as the end of the radius.

Simplifications:

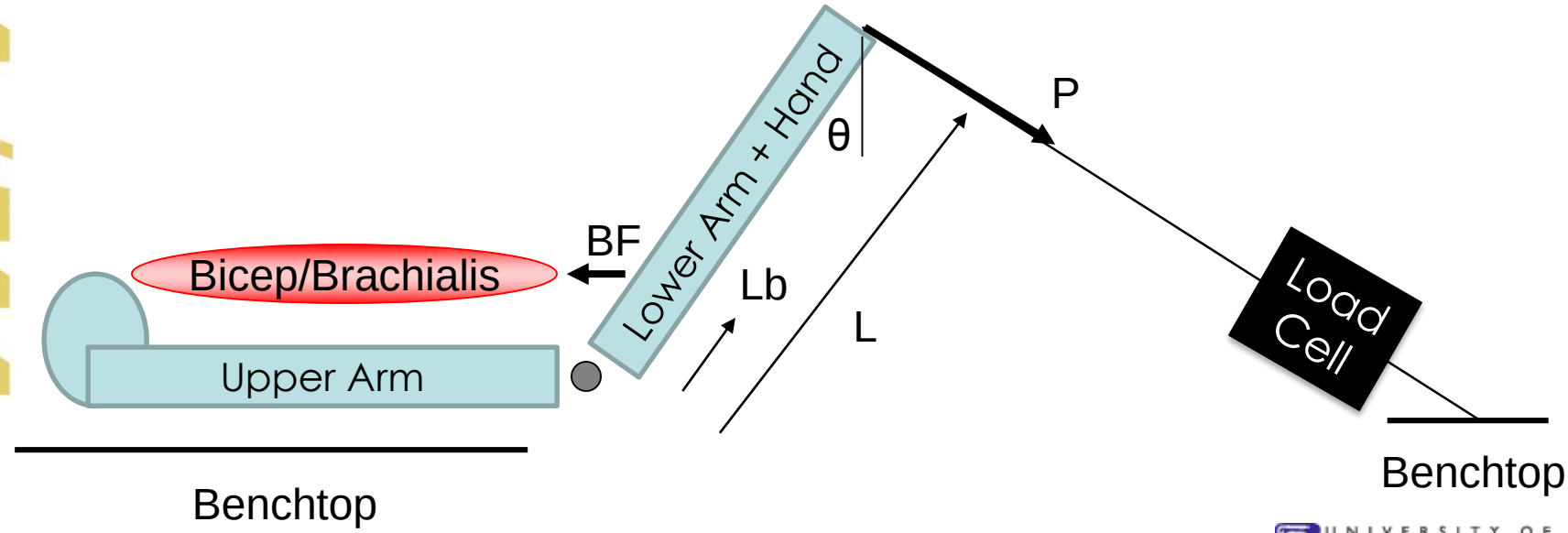
1. PCSA = $A_{muscle} = V_{muscle} / L_{muscle}$
2. Muscle force areal density:

$w = 20$ N/cm^2 [McMahon, 1984]

Isometric Part

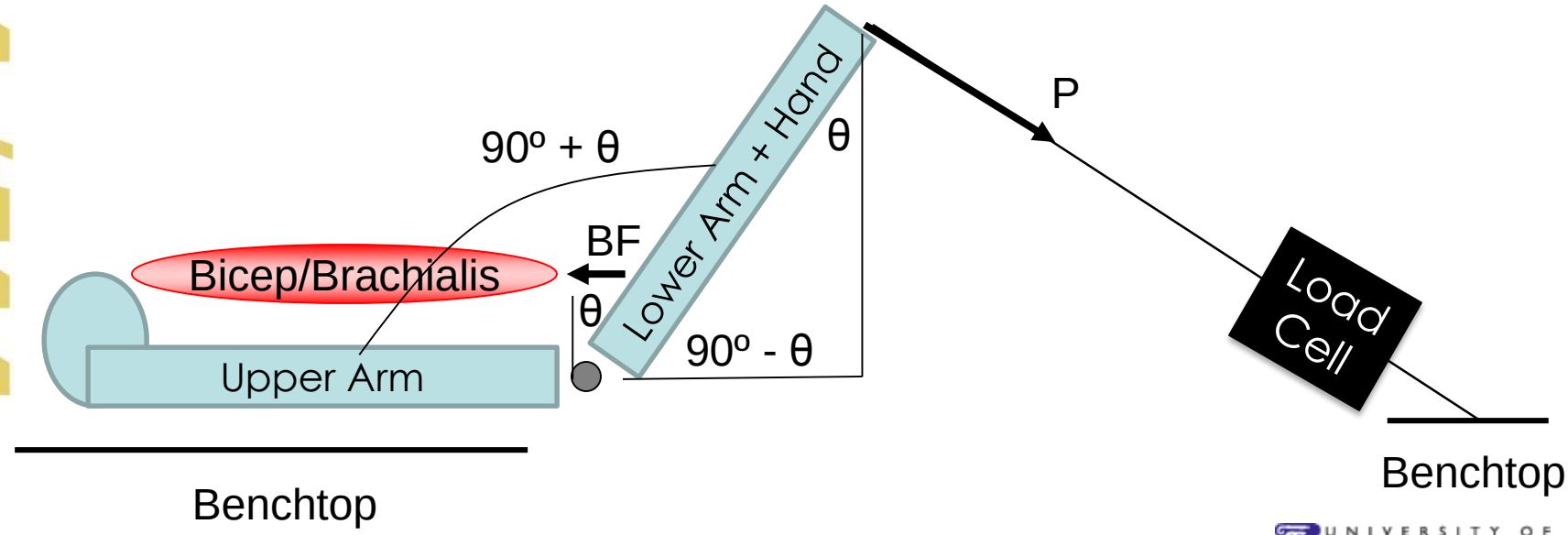
Free Body Diagram

P	load cell
L	elbow-to-grip length
BF	bicep force
Lb	elbow-to-attachment length
θ	angle of handle



Free Body Diagram

Use trigonometry to find the arm angle and other important angles



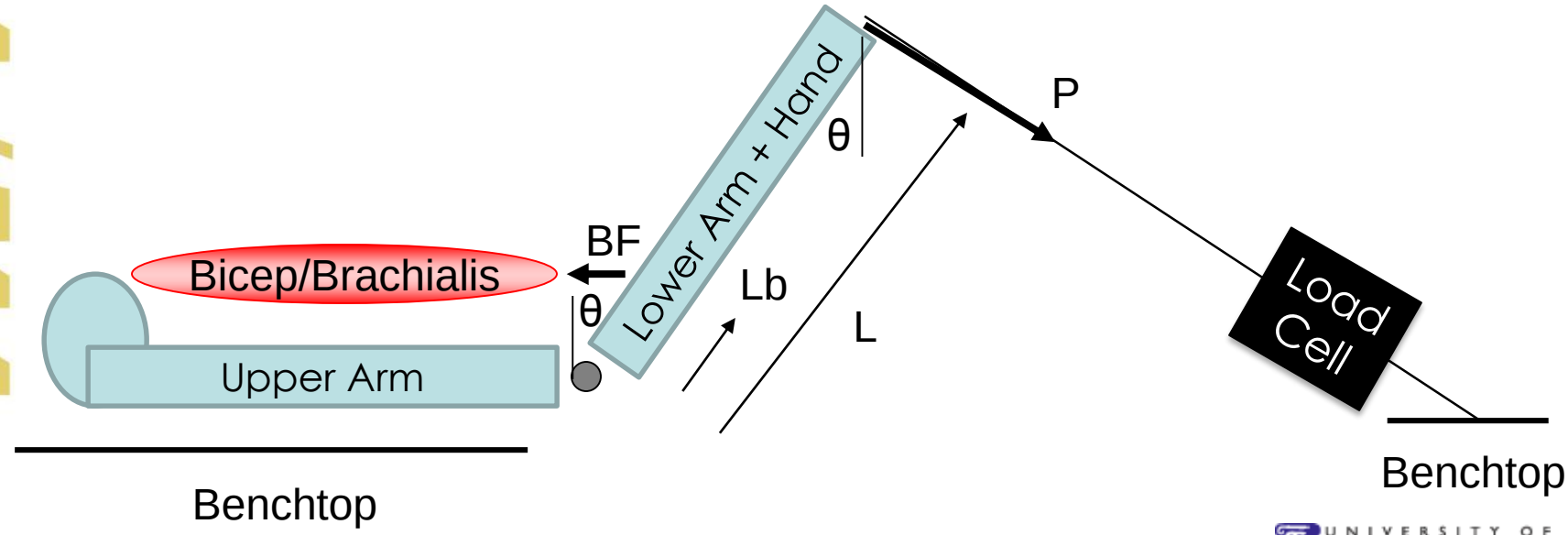
Free Body Diagram

Use sum of the moments to find BF:

$$M = (L \otimes P) + (Lb \otimes BF)$$

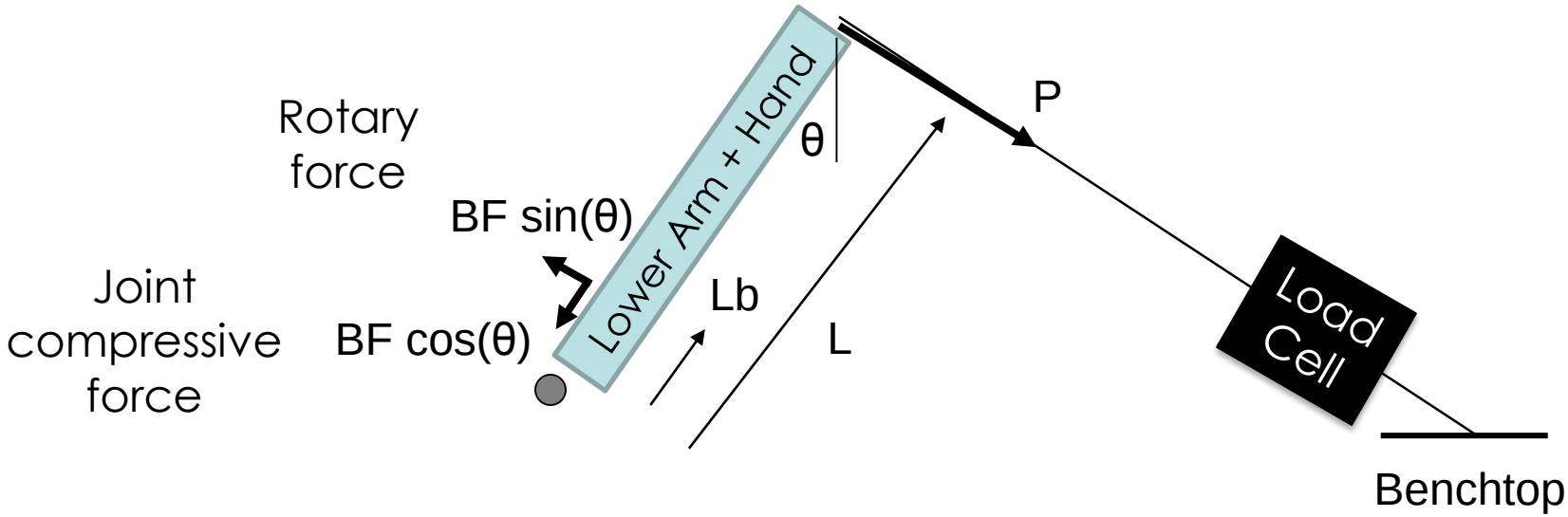
where,

$\otimes$ = cross product



Free Body Diagram

$$M = (L \otimes P) + (Lb \otimes BF)$$



Isotonic Part

Isotonic Part

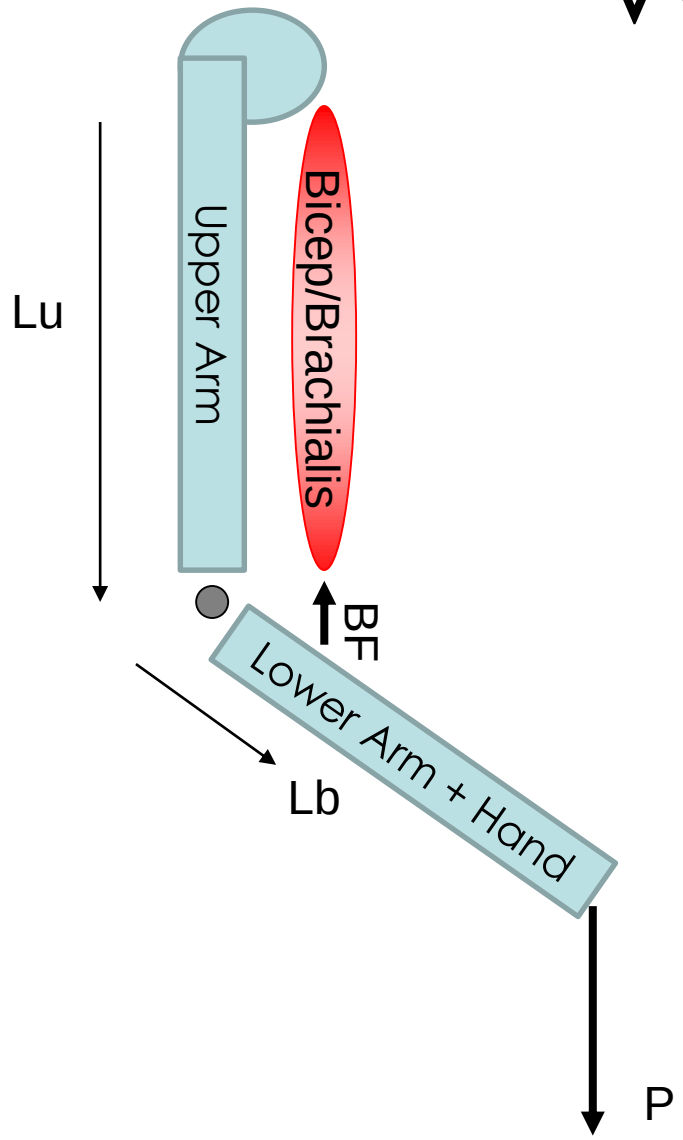
Good Lift

- Good posture
- Steady lift
- Ideal weight

Bad Lift

- Leaning posture
- Rocking shoulder
- Too much weight

Velocity



$V = \Delta L / \Delta t$

$\Delta L = L\_extend - L\_curled$

$L\_extend \approx Lu + Lb$

$L\_curled \approx Lu - Lb \cos(\theta)$

θ... arm angle

Δt … from camera

CoachMyVideo

- Available for iPhones and iPads
- Suggestions for a free frame-by-frame video player for Android?
  - QuikCoach

Questions?