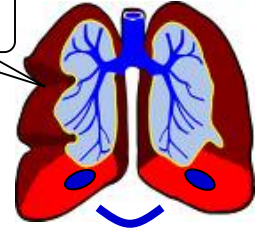


## BI 121 Lecture 15

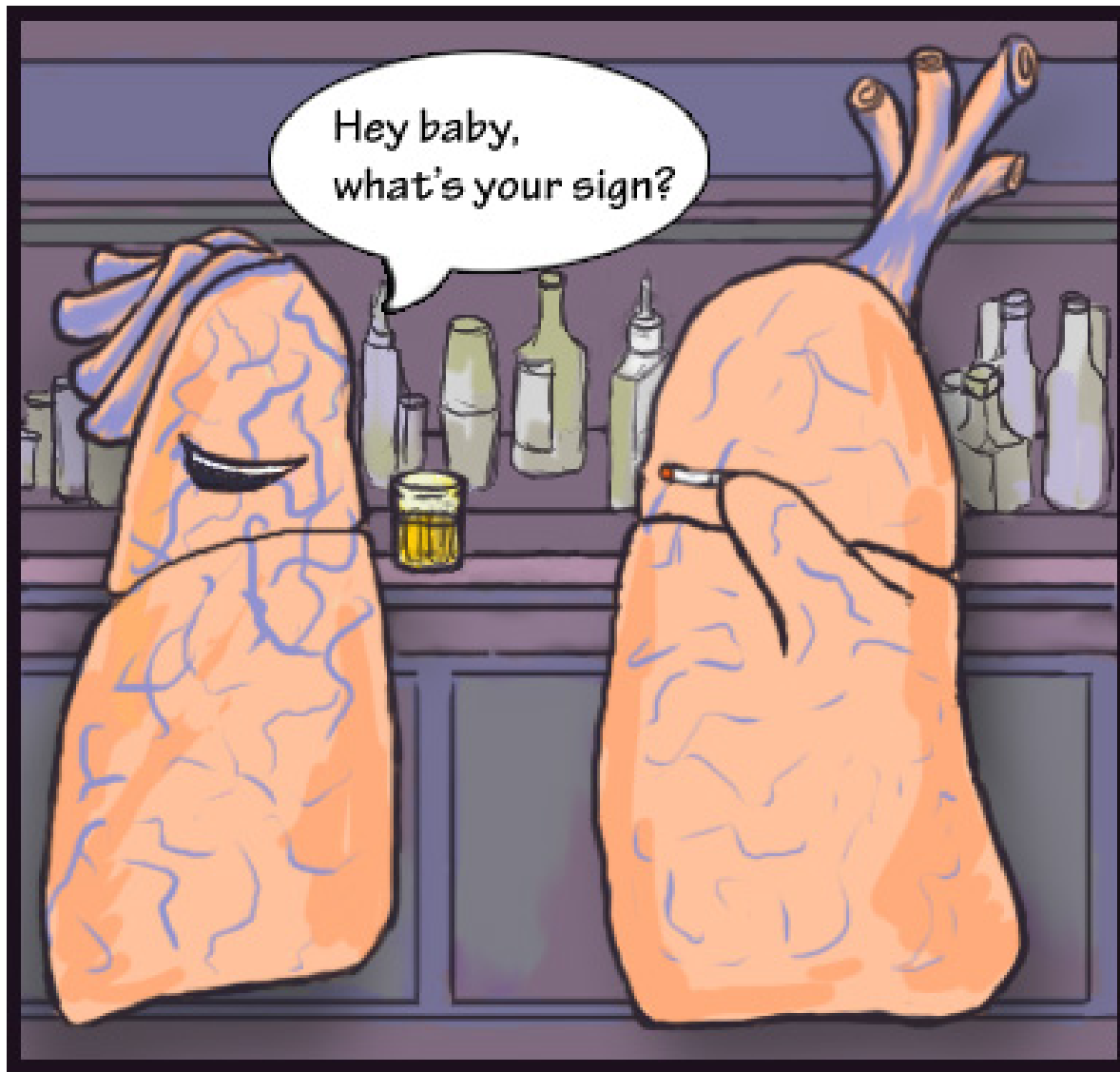


Fun lab with personal lifetime data!

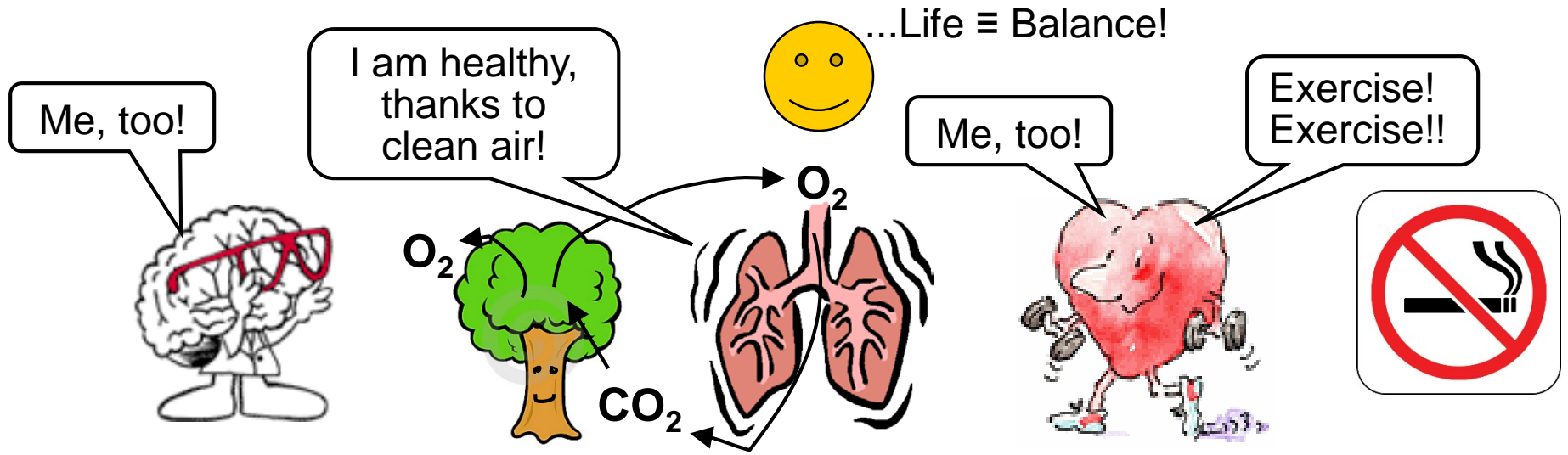
Yes!!



- I. Announcements** Lab 6, Pulmonary Function Testing (PFT) + optional notebook check today. Exam II Dec 8 Tuesday, 8 am!
- II. Introduction to PFT Lab 6** Pulmonary Function Testing
- III. Connections: Muscle Contraction+Adaptation** DC Mod 12+
  - A.** Review of structure + banding pattern? LS fig 8-2 thru 8-5
  - B.** How do muscles contract? LS fig 8-6, 8-10, 8-11 +...
  - C.** Summary of skeletal muscle contraction with videos  
Courtesy David Bolinsky, *XVIVO* & Malcolm Campbell, Department of Biology, Davidson College, NC +...
  - D.** Exercise adaptation variables LS ch 8 pp 210-214  
*mode, intensity, duration, frequency, distribution of training sessions, individual & environmental factors*
  - E.** *Endurance vs. Strength* training continuum? fiber types...



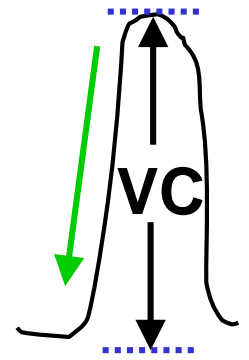
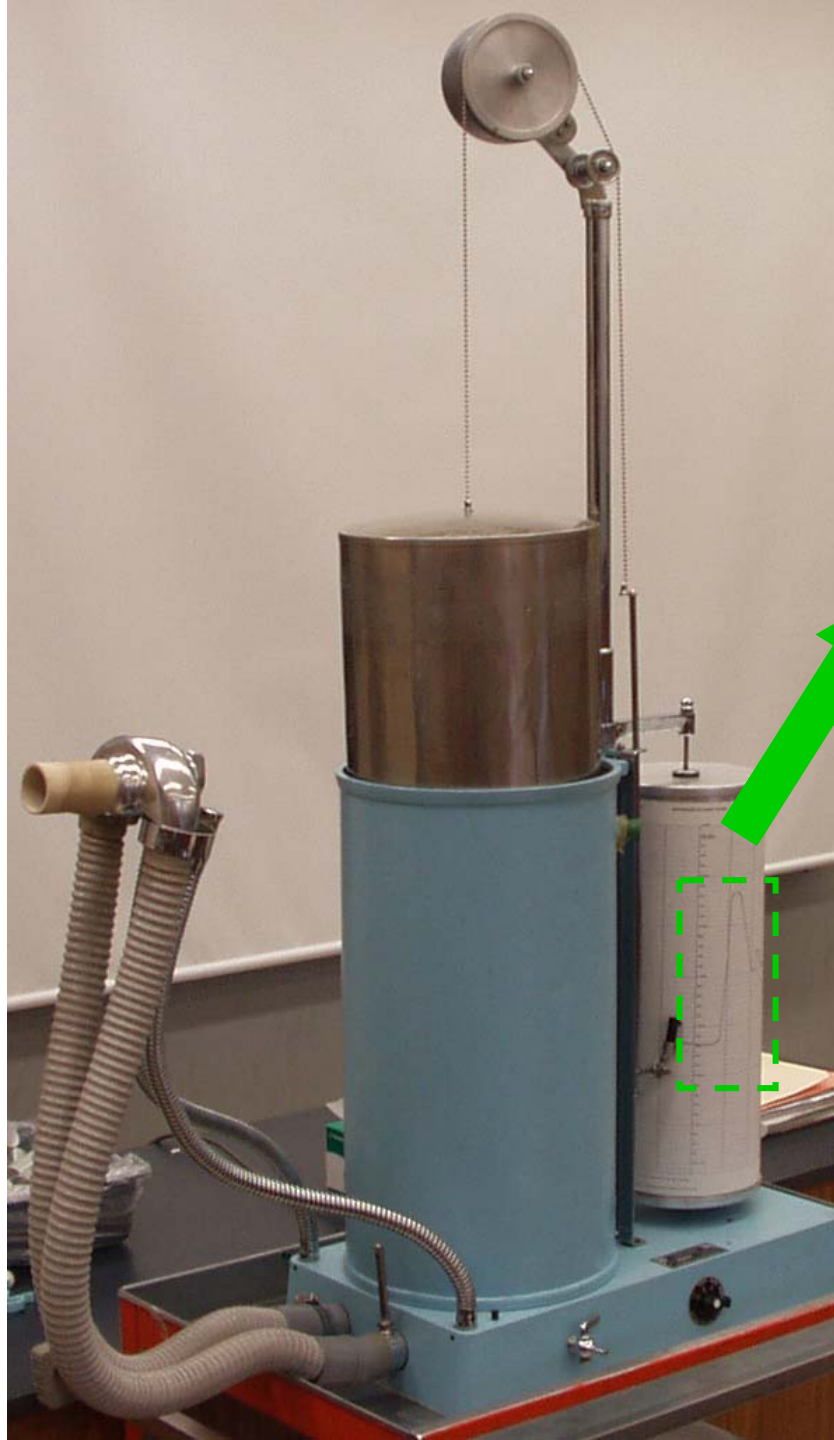
**Cancer.**



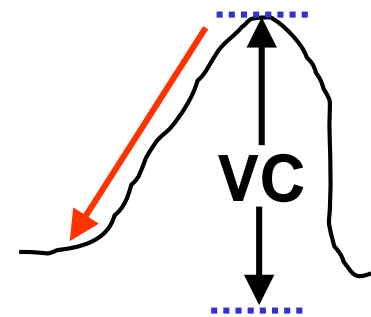
# ***Lab 6 Review: Pulmonary Function Testing (PFT)***

**Respirometer** →  
measures **complete  
Pulmonary Function  
Test or PFT!**

**NB:** Should be able to  
blow out  $\geq 75 - 85\%$  of  
VC/FVC in 1 second!  
That's  $FEV_{1.0}/FVC \geq$   
 $0.75 - 0.85$ . If less,  
may indicate asthma  
or other lung disease.

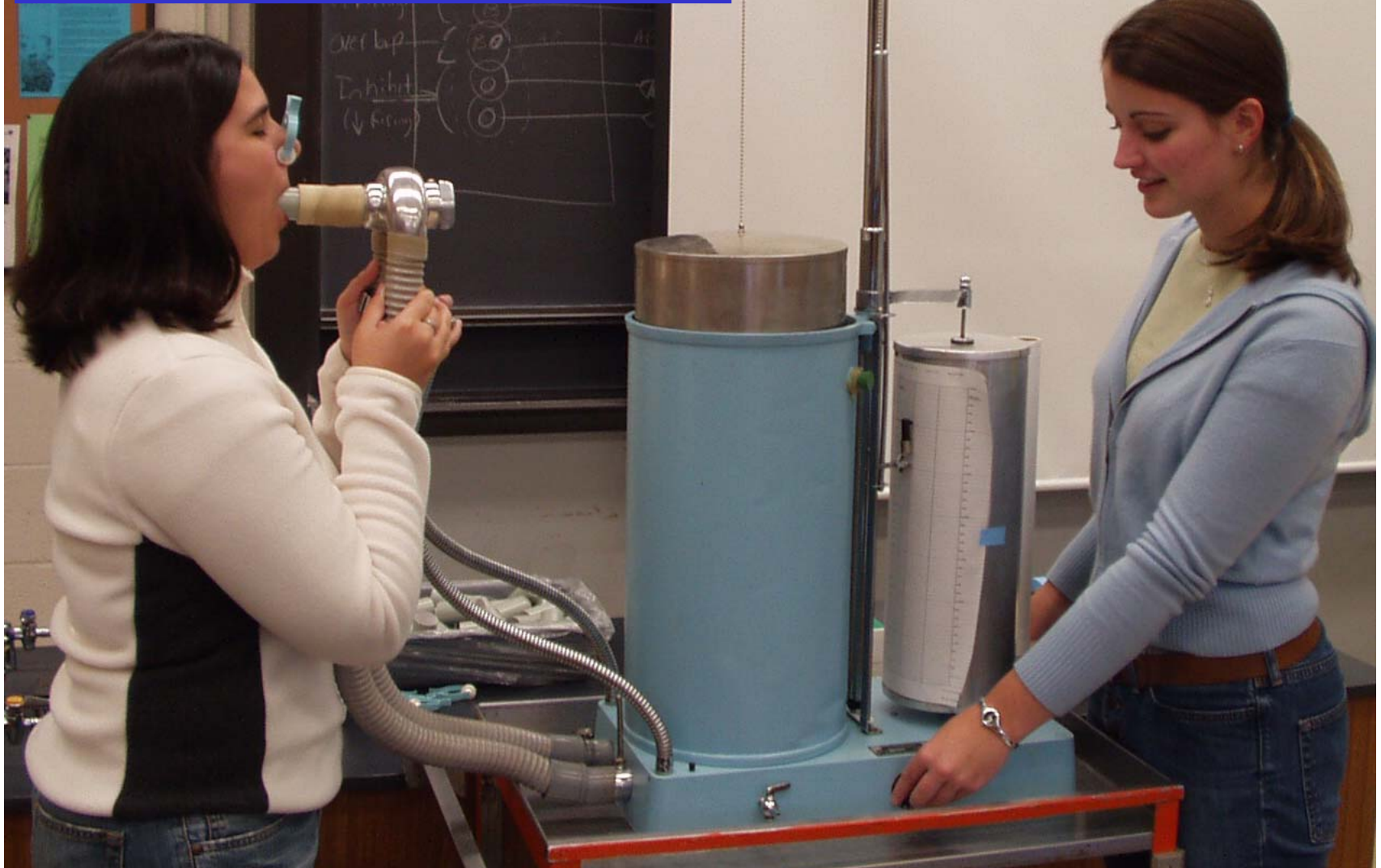


**Normal =  
Steep**

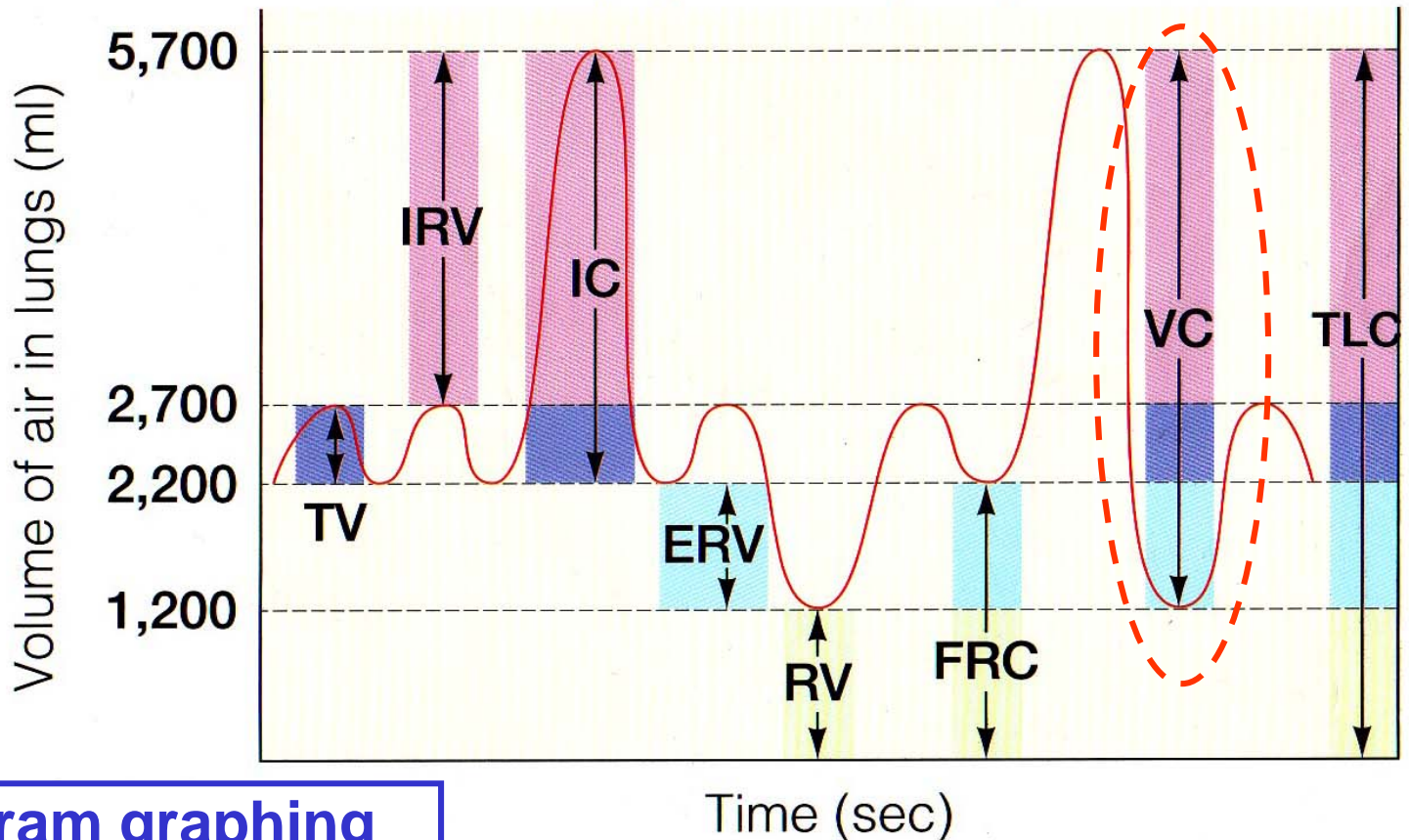


**Abnormal =  
Flatter  
Downslope  
(eg, Asthma)**

**PFT** → measures all lung volumes & capacities (sum of  $\geq 2$  volumes). Subject relaxes & breathes normally into and out of tank.



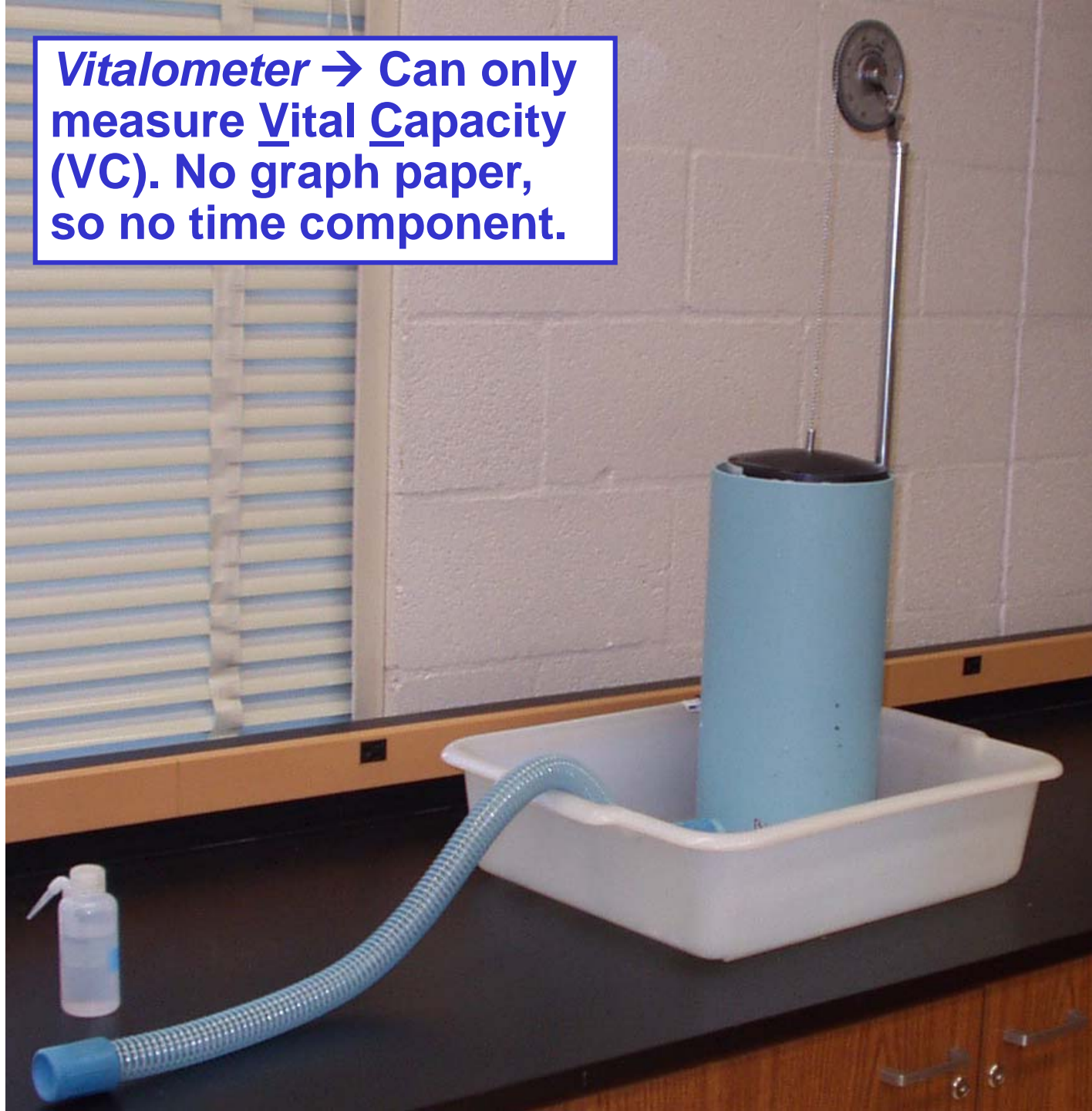
## Normal Spirogram of Healthy Young Adult Male



**Spirogram graphing  
complete *PFT* from  
computer simulation.**

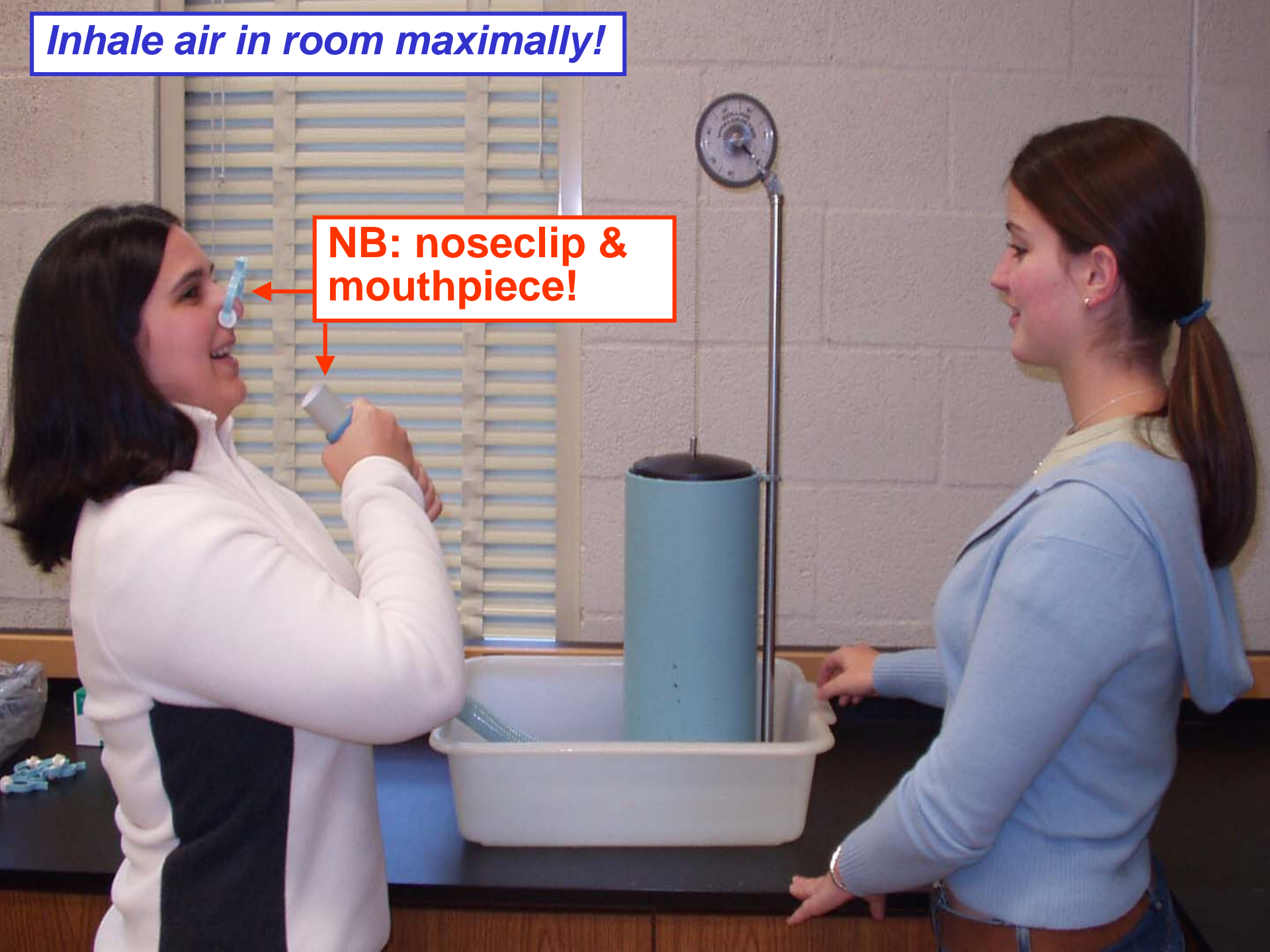
- TV = Tidal volume (500 ml)
- IRV = Inspiratory reserve volume (3,000 ml)
- IC = Inspiratory capacity (3,500 ml)
- ERV = Expiratory reserve volume (1,000 ml)
- RV = Residual volume (1,200 ml)
- FRC = Functional residual capacity (2,200 ml)
- VC = Vital capacity (4,500 ml)
- TLC = Total lung capacity (5,700 ml)

***Vitalometer* → Can only measure Vital Capacity (VC). No graph paper, so no time component.**



***Inhale air in room maximally!***

**NB: noseclip & mouthpiece!**





***Exhale into tube maximally!***



# *More modern-day computerized Pulmonary Function Testing*



*Complete with HH!  
Happy Helpers!*

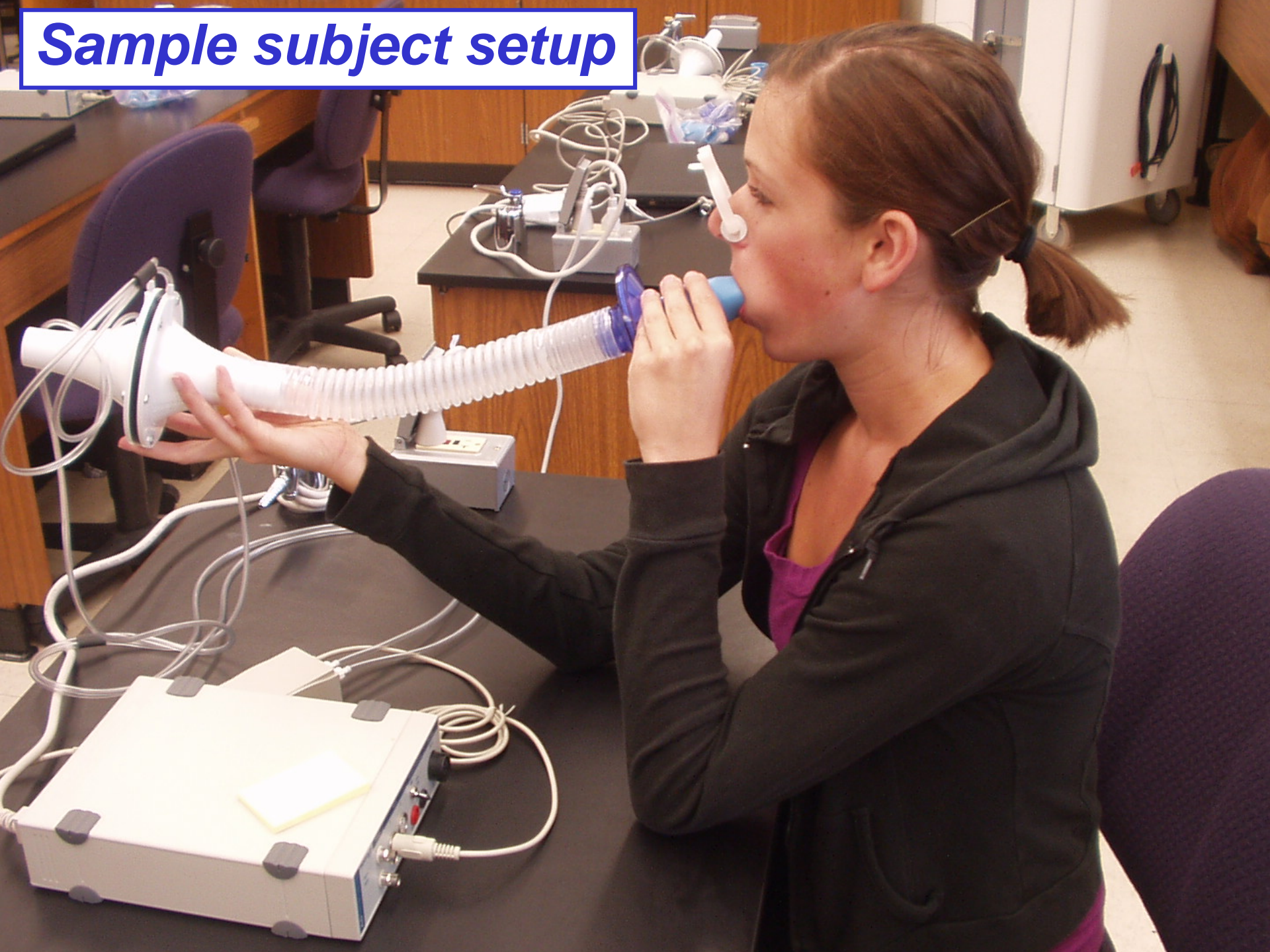


**How to put  
together?**

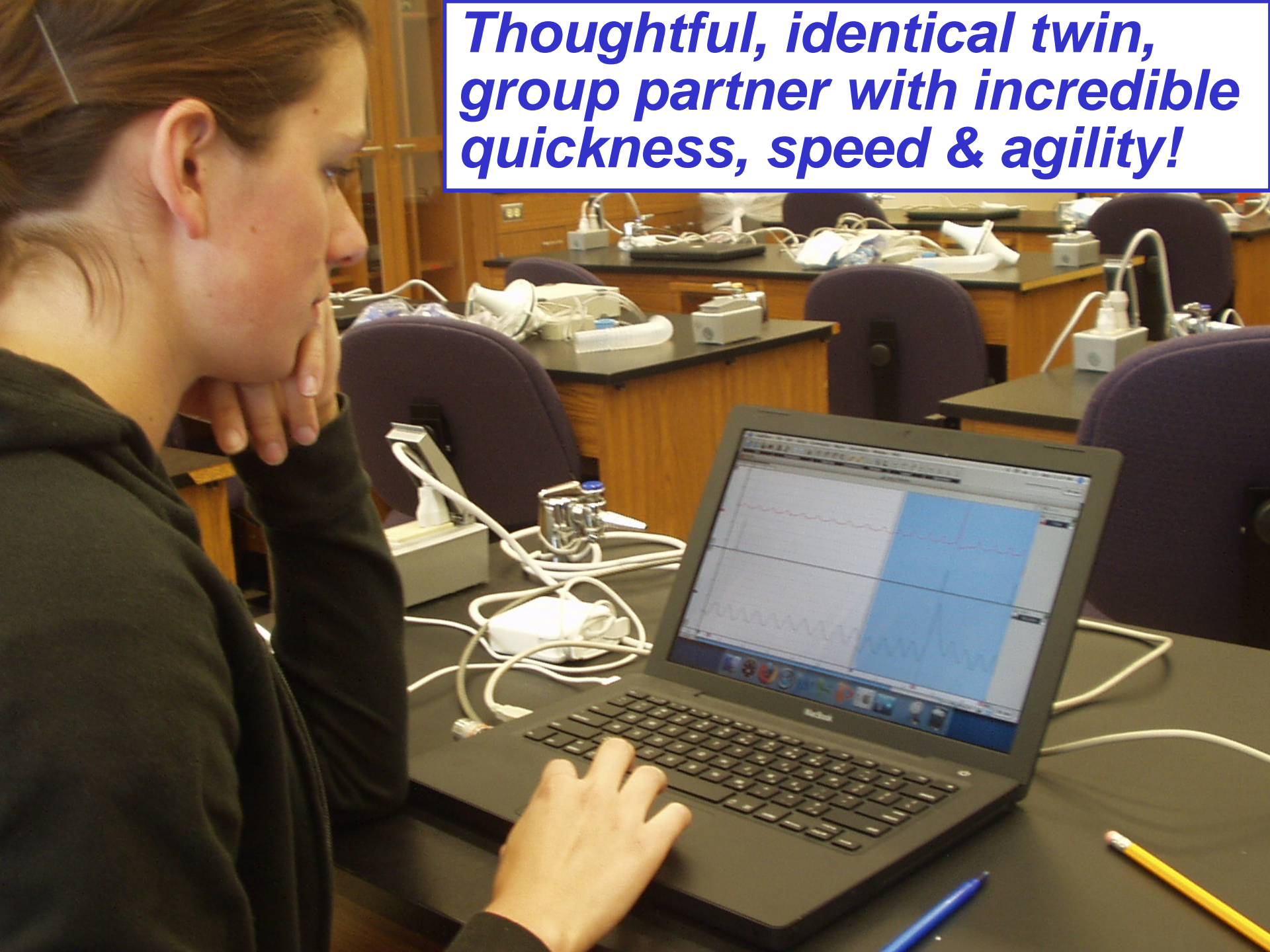
**Viola!!**



# *Sample subject setup*

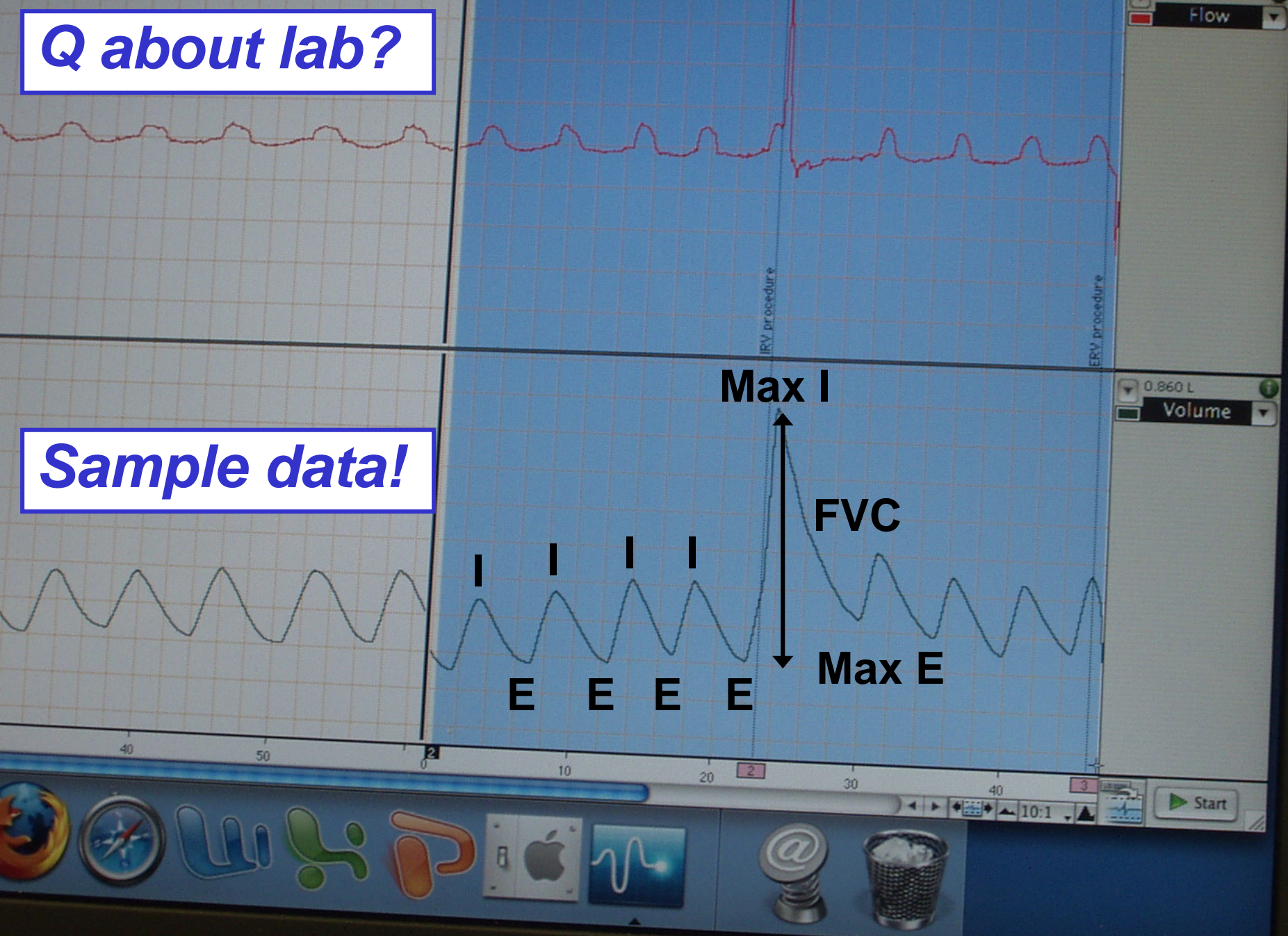


***Thoughtful, identical twin,  
group partner with incredible  
quickness, speed & agility!***



**Q about lab?**

**Sample data!**

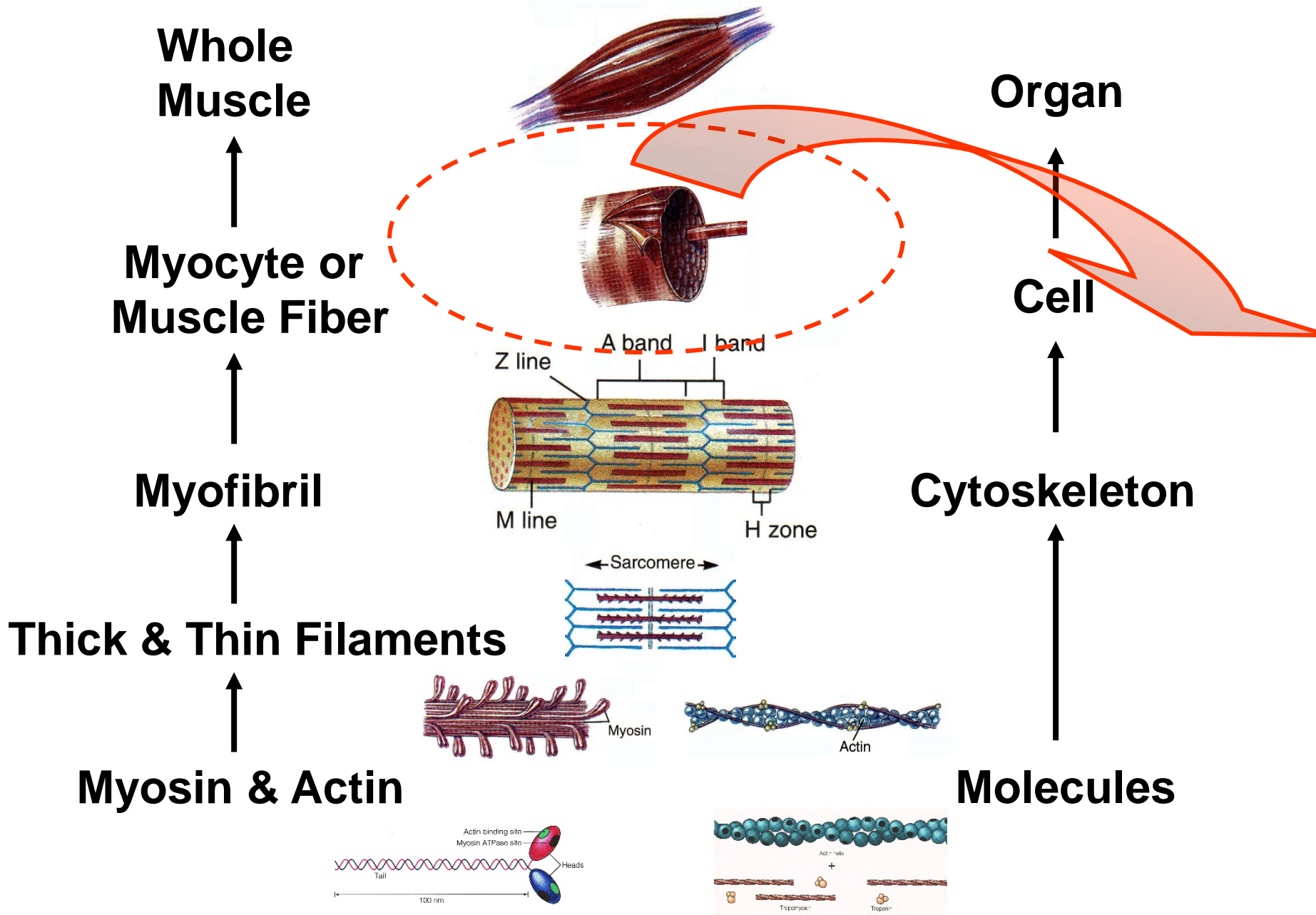


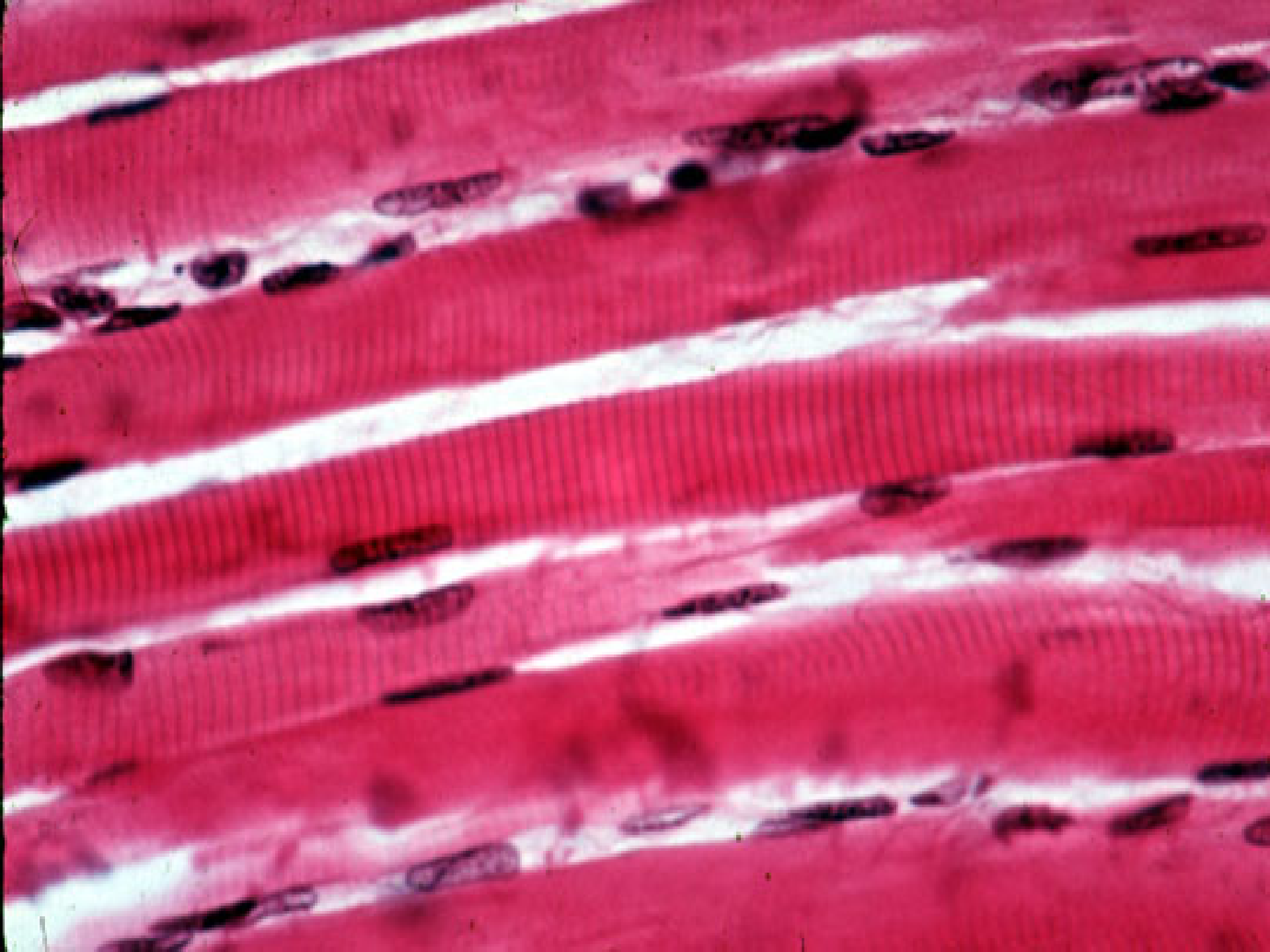
MacBook

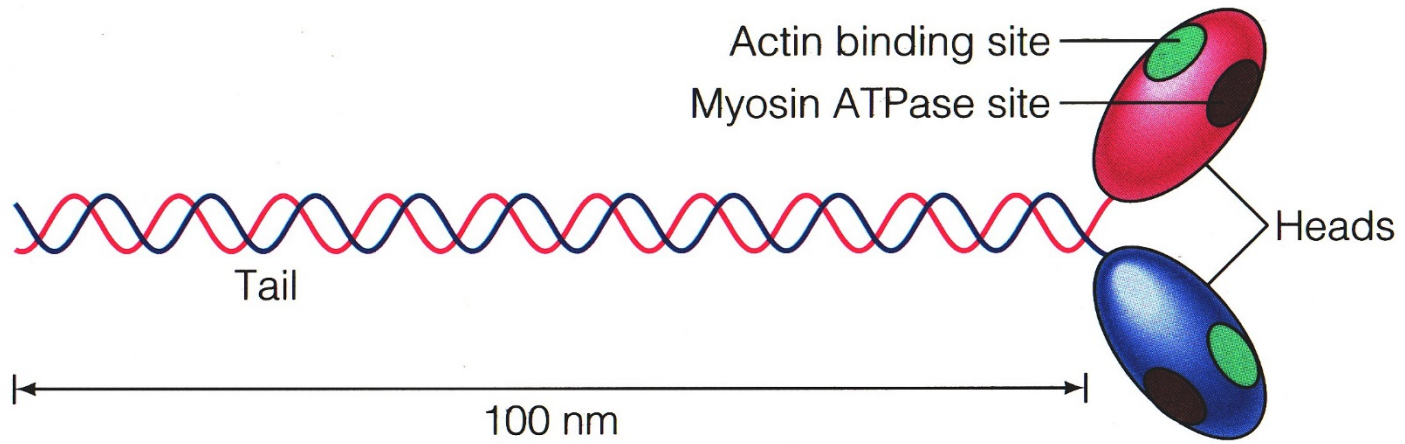
# *Questions/Discussion?*





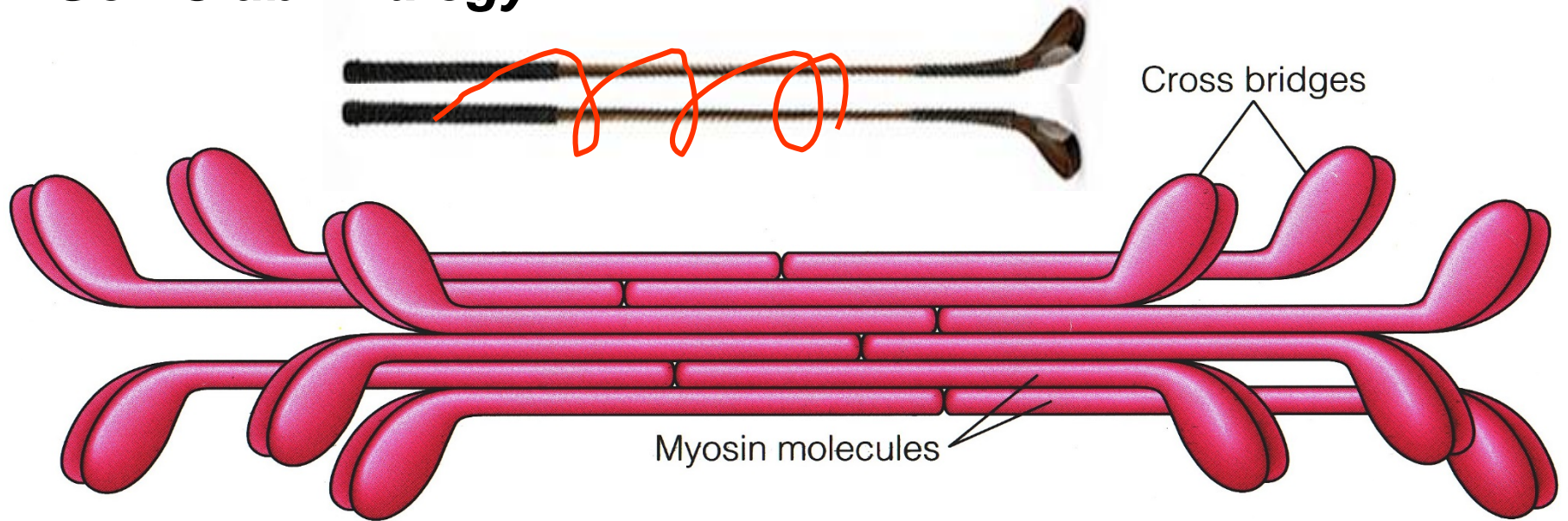






(a)

## ***Golf Club Analogy?***



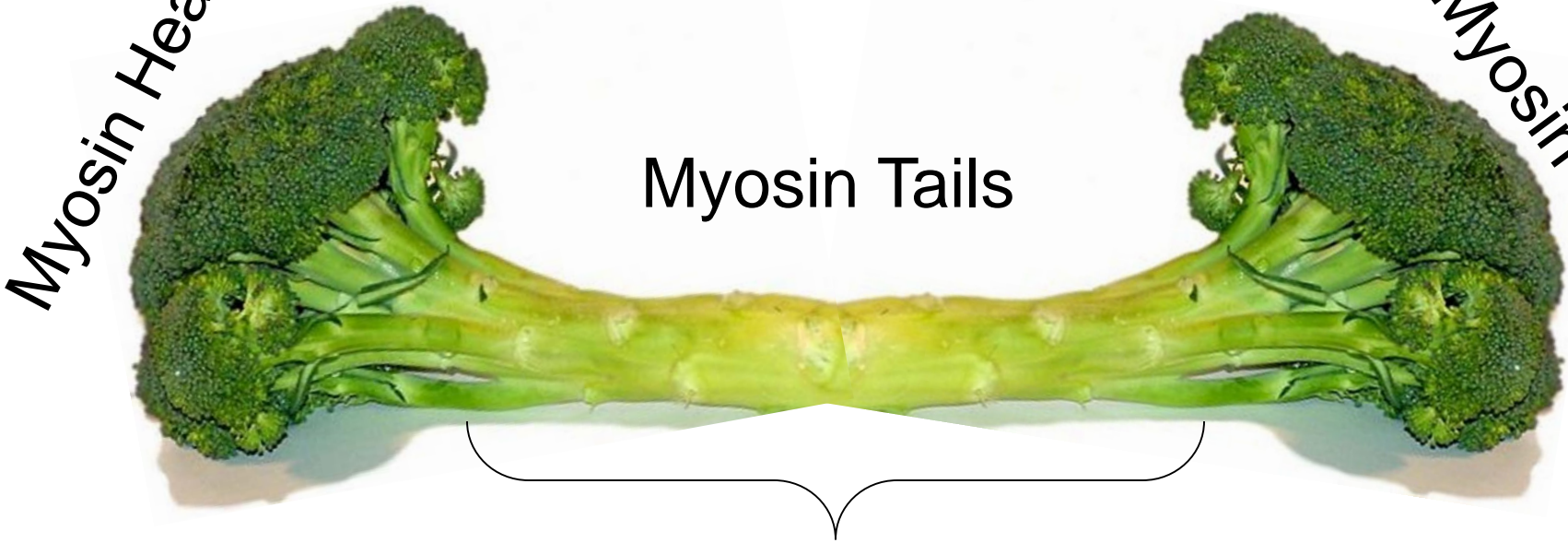
(b)

# *Broccoli Analogy?*

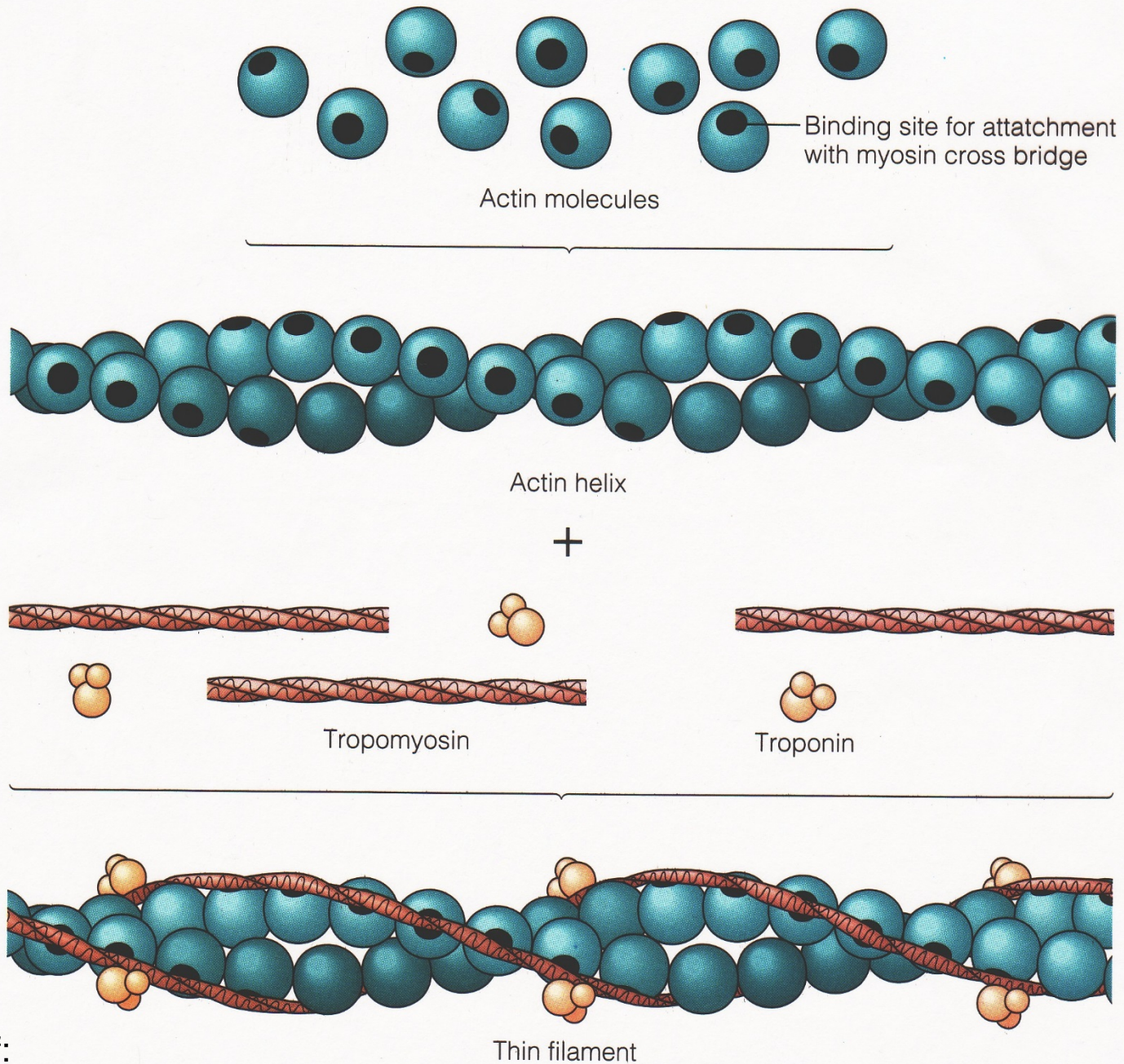
*Myosin Heads*

*Myosin Heads*

Myosin Tails



Bare Zone



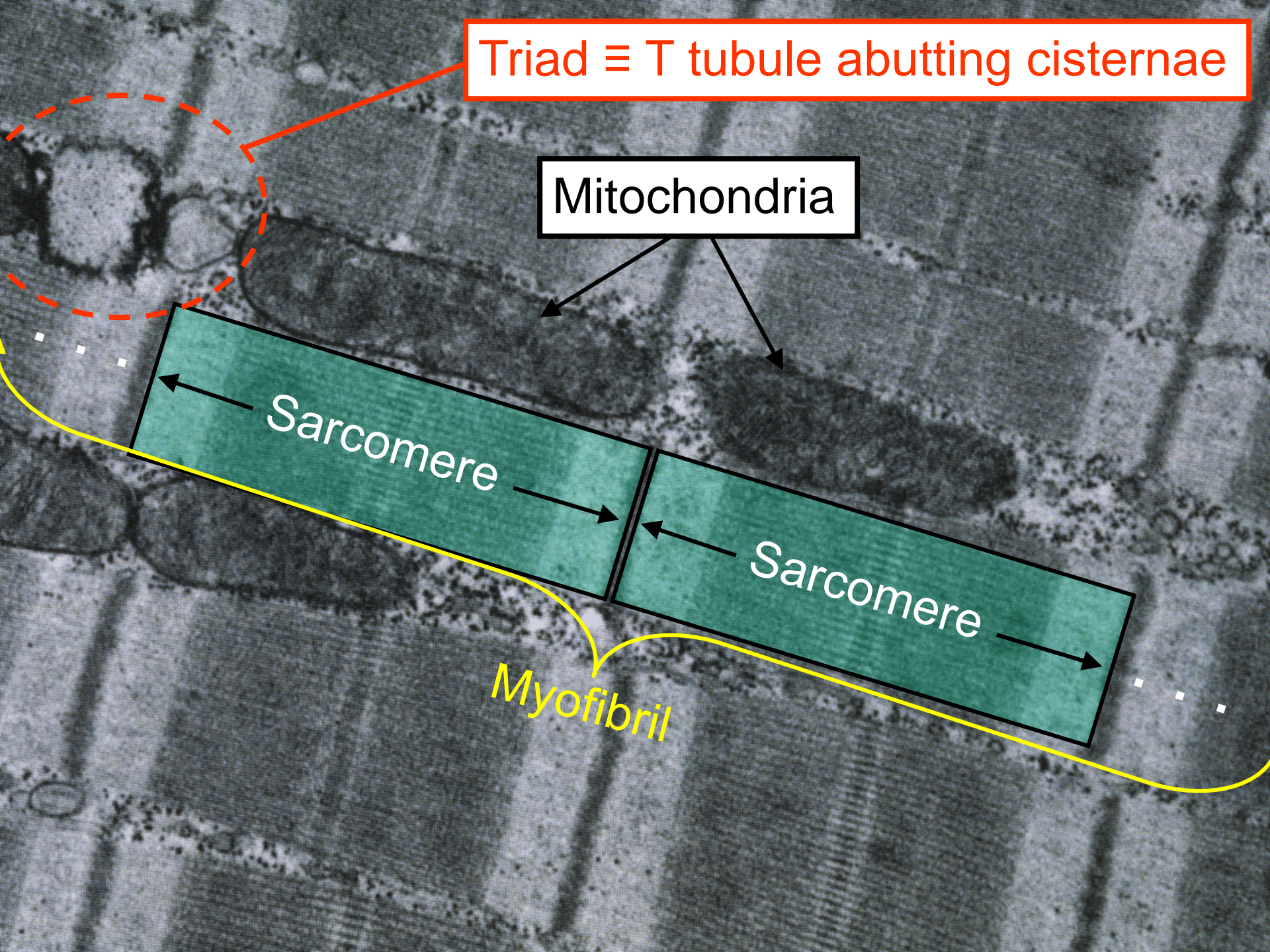
Triad  $\equiv$  T tubule abutting cisternae

Mitochondria

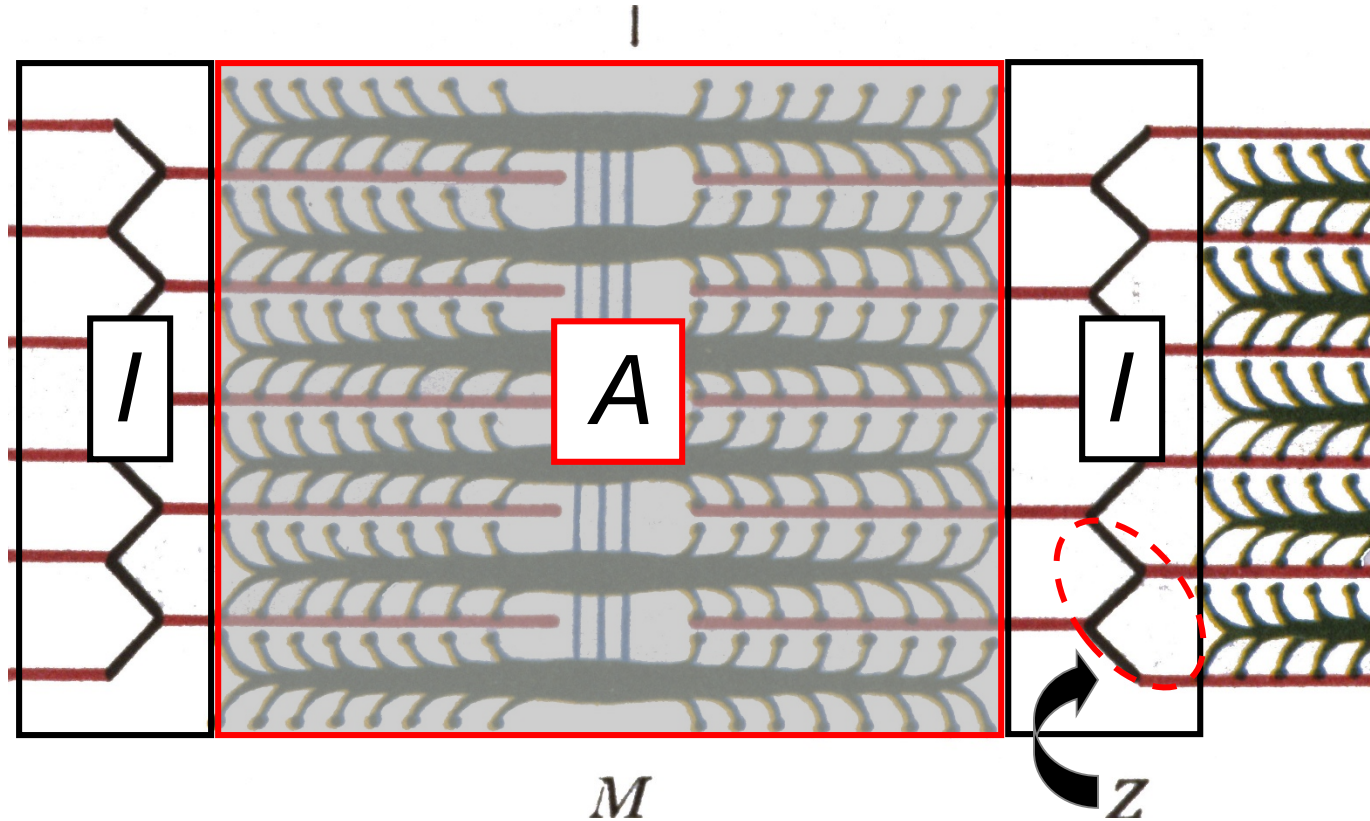
Sarcomere

Sarcomere

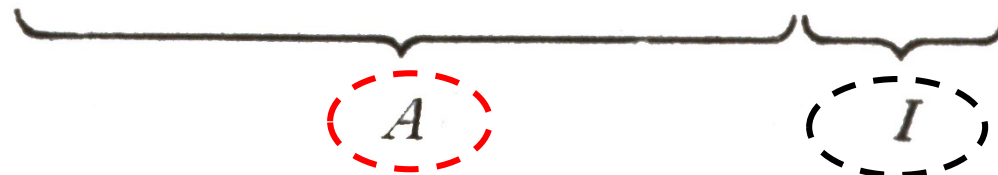
Myofibril

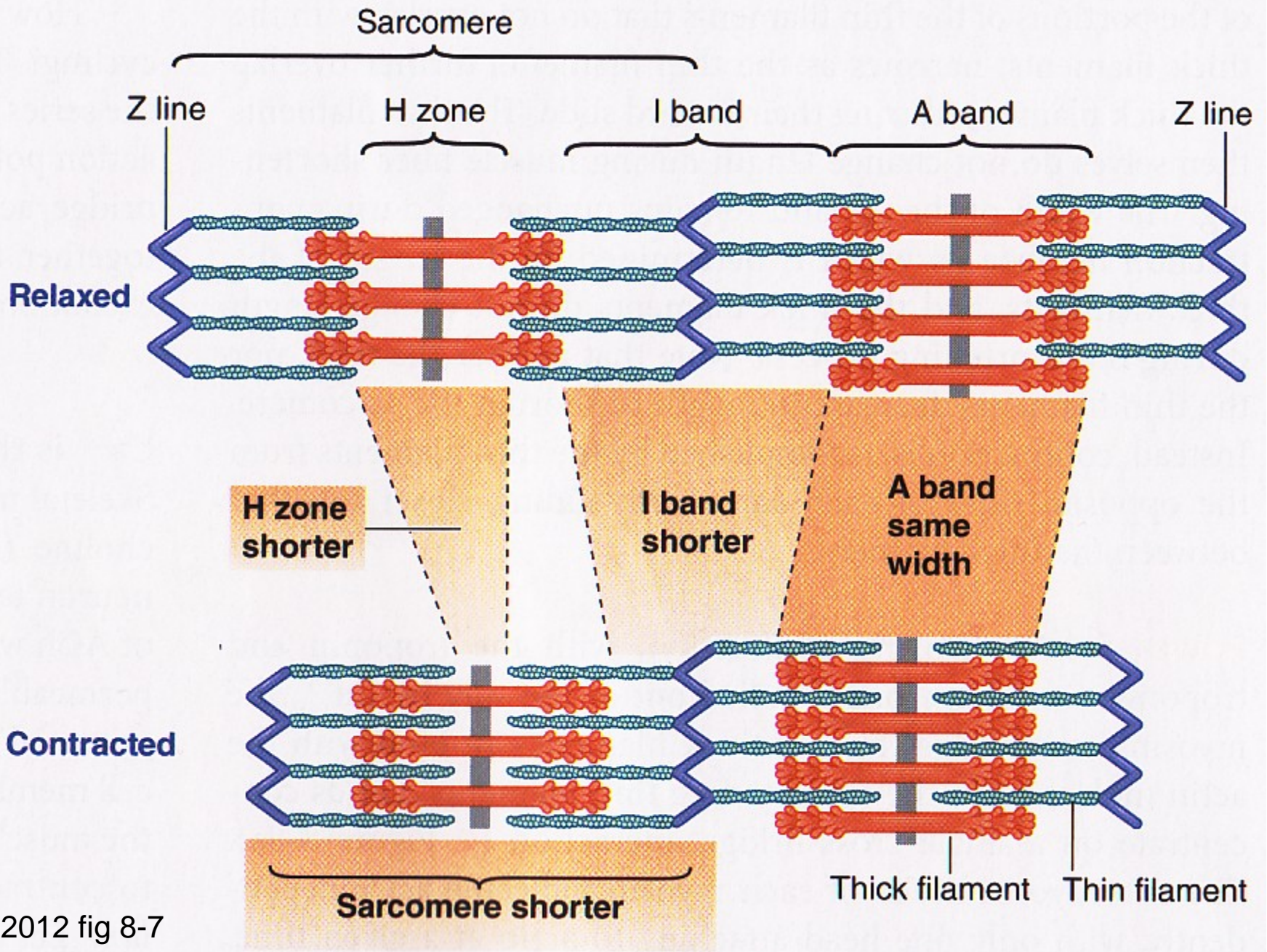


A Band = Dark Band  
Anisotropic = Light Can't Shine Through



I Band = Light Band  
Isotropic = Light Can Shine Through



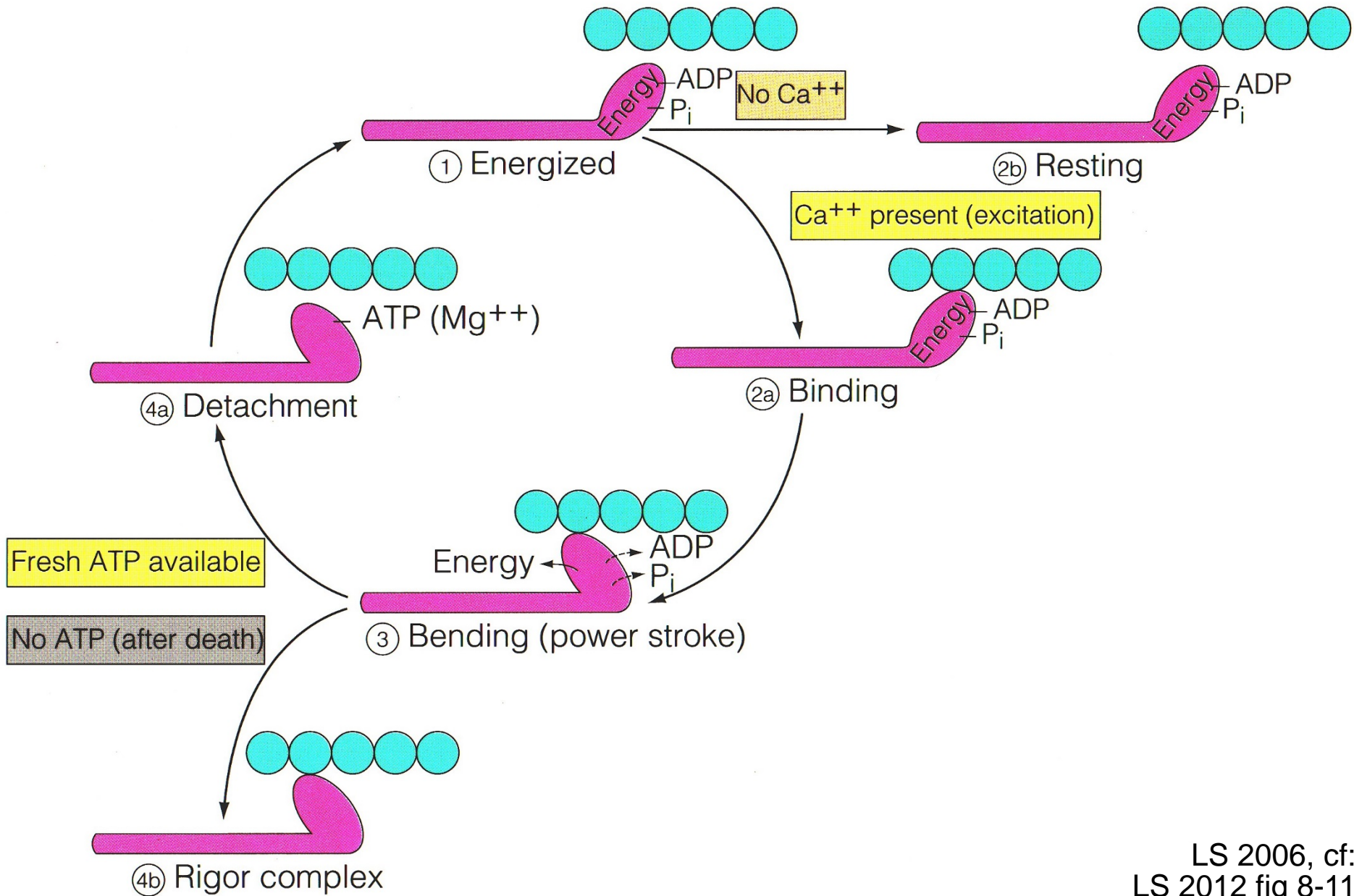


LS 2012 fig 8-7

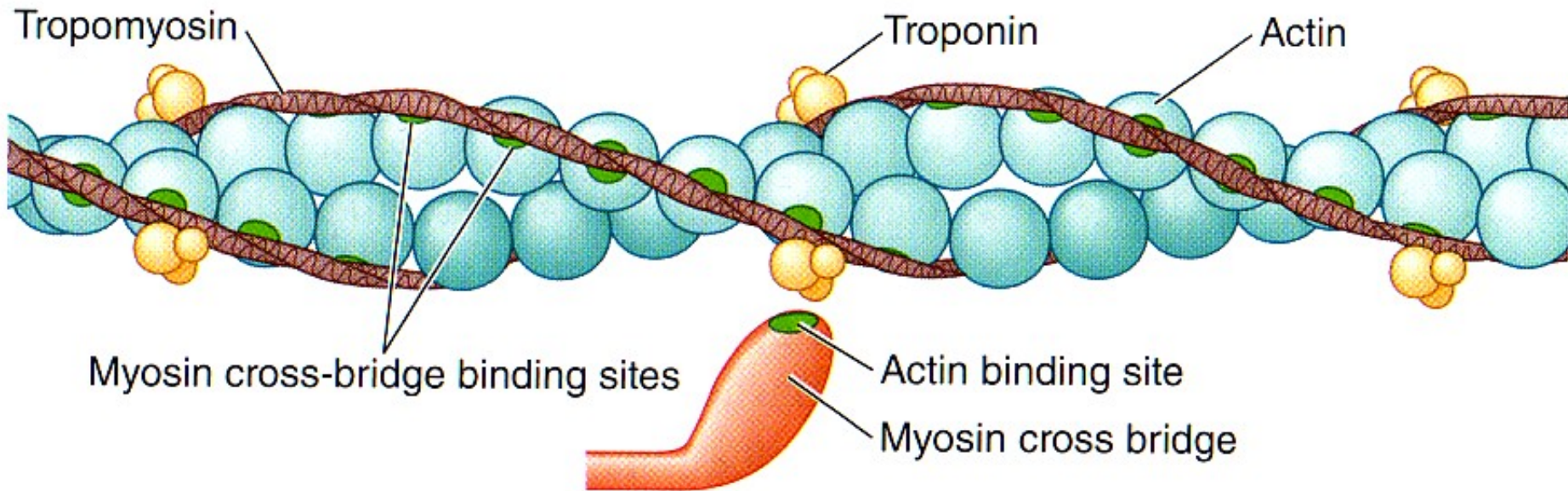


***What do we guess  
happens at the  
molecular level?***

# Cross-Bridge Cycle



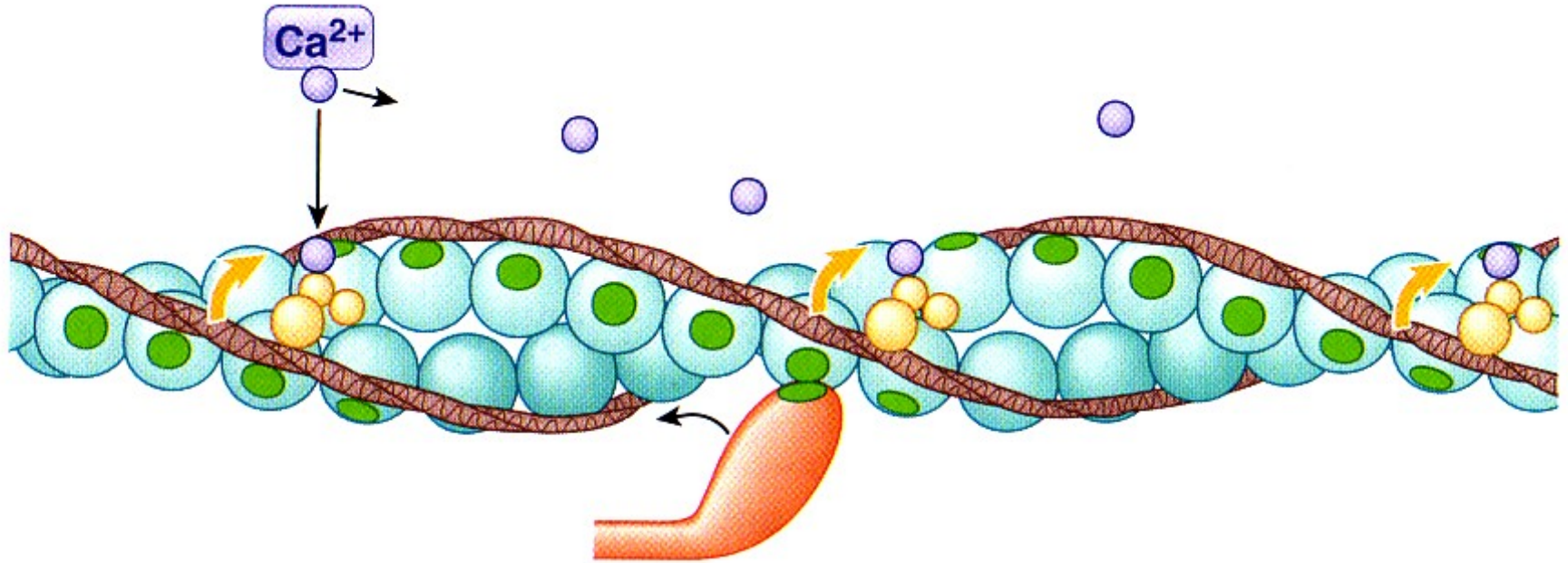
# ***Relaxed: No Cross-Bridge Binding***



## **(a) Relaxed**

- 1** No excitation.
- 2** No cross-bridge binding because cross-bridge binding site on actin is physically covered by troponin–tropomyosin complex.
- 3** Muscle fiber is relaxed.

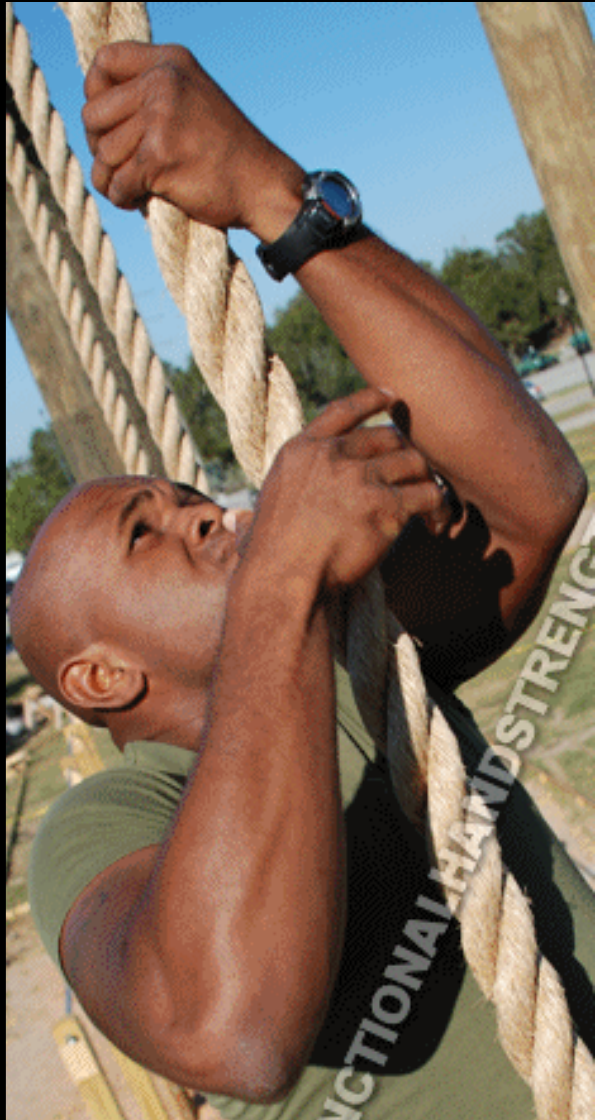
# *Excited: Calcium Triggers Cross-Bridge Binding*



## **(b) Excited**

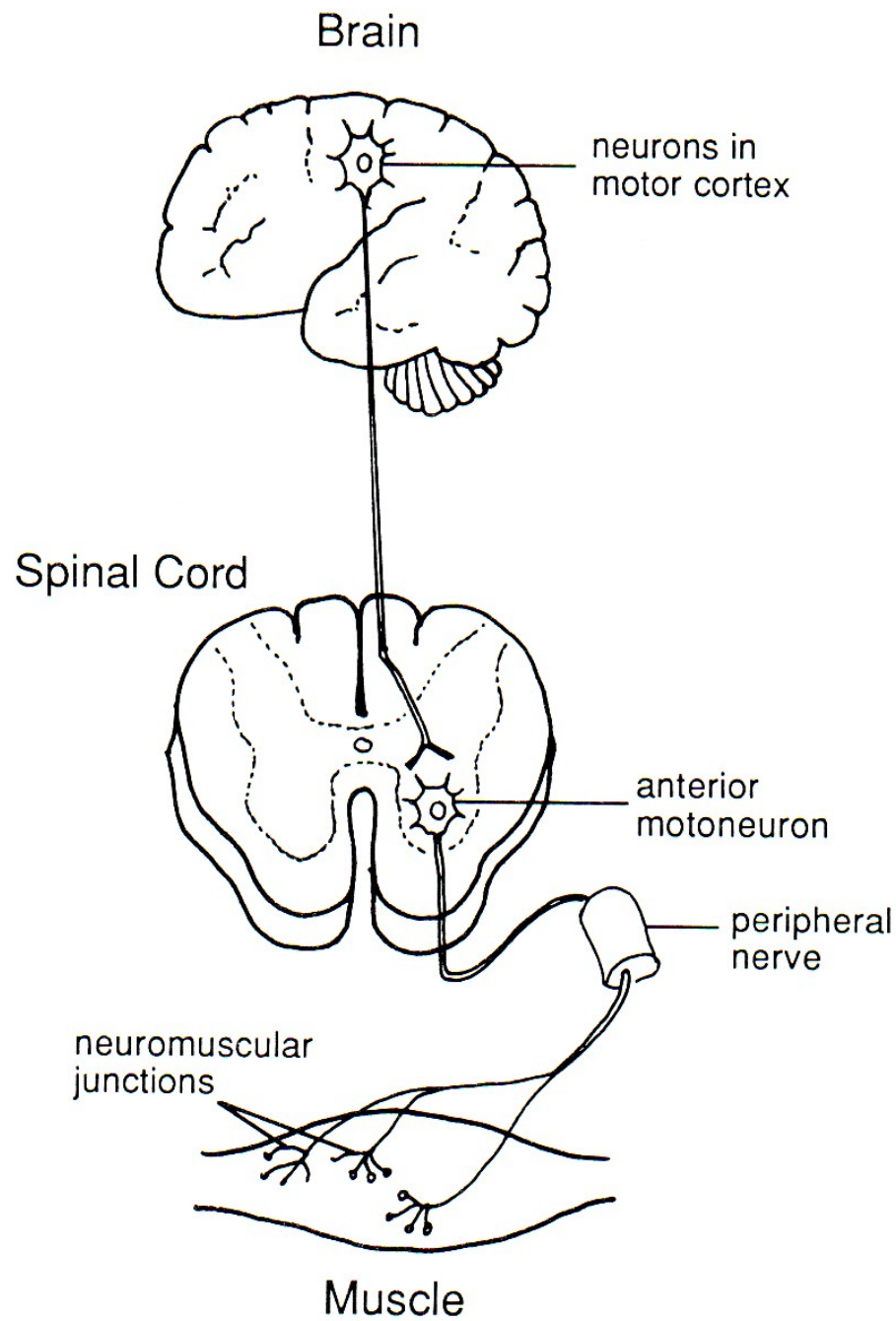
- 1** Muscle fiber is excited and  $\text{Ca}^{2+}$  is released.
- 2** Released  $\text{Ca}^{2+}$  binds with troponin, pulling troponin–tropomyosin complex aside to expose cross-bridge binding site.
- 3** Cross-bridge binding occurs.
- 4** Binding of actin and myosin cross bridge triggers power stroke that pulls thin filament inward during contraction.

# *Rope Climb or Tug of War Grasp, then Regrasp!*



# *Summary*

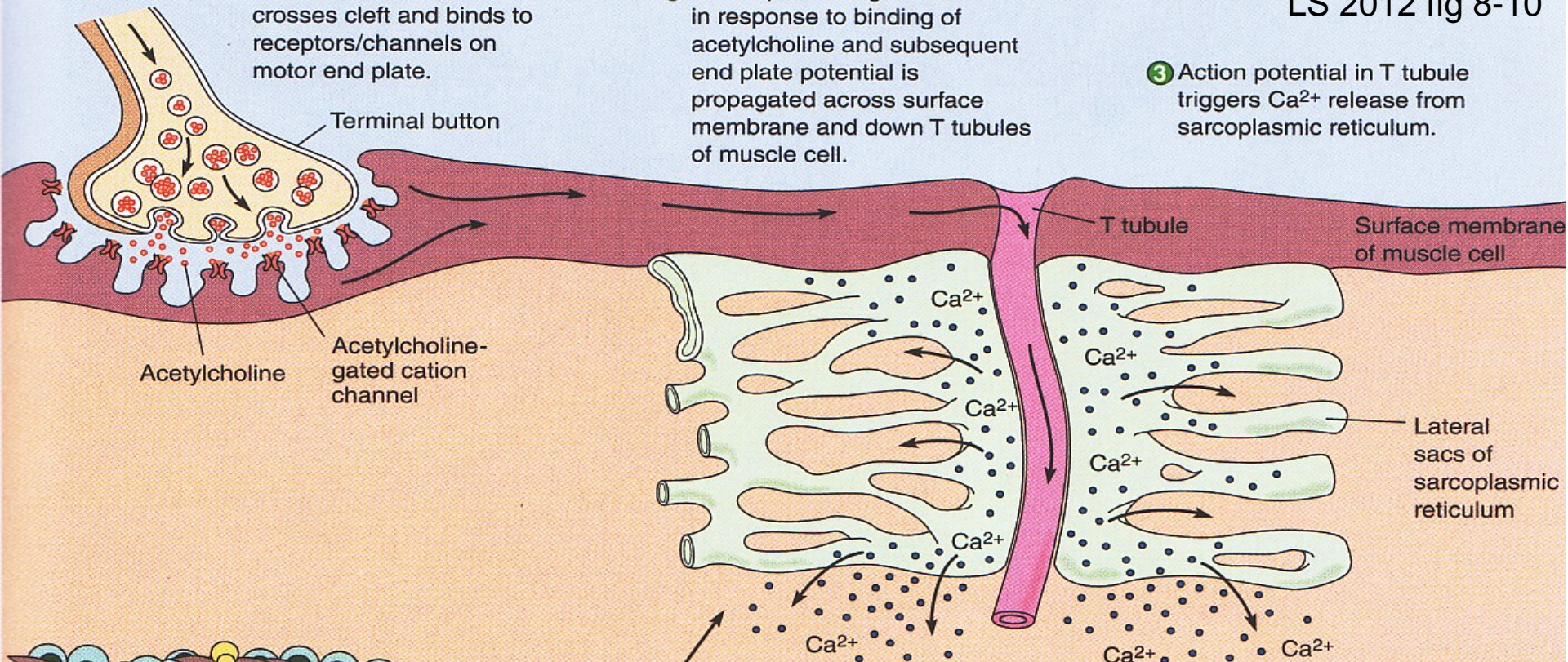




1 Acetylcholine released by axon of motor neuron crosses cleft and binds to receptors/channels on motor end plate.

2 Action potential generated in response to binding of acetylcholine and subsequent end plate potential is propagated across surface membrane and down T tubules of muscle cell.

3 Action potential in T tubule triggers  $\text{Ca}^{2+}$  release from sarcoplasmic reticulum.



Terminal button  
Acetylcholine  
Acetylcholine-gated cation channel

T tubule  
Surface membrane of muscle cell

Lateral sacs of sarcoplasmic reticulum

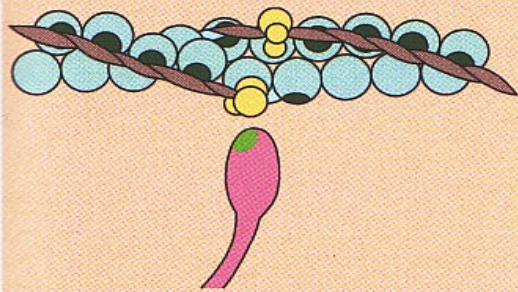
$\text{Ca}^{2+}$   
 $\text{Ca}^{2+}$   
 $\text{Ca}^{2+}$   
 $\text{Ca}^{2+}$   
 $\text{Ca}^{2+}$   
 $\text{Ca}^{2+}$

7 With  $\text{Ca}^{2+}$  no longer bound to troponin, tropomyosin slips back to its blocking position over binding sites on actin; contraction ends; actin passively slides back to original resting position.

6  $\text{Ca}^{2+}$  actively taken up by sarcoplasmic reticulum when there is no longer local action potential.

5 Myosin cross bridges attach to actin and bend, pulling actin filaments toward center of sarcomere; powered by energy provided by ATP.

4 Calcium ions released from lateral sacs bind to troponin on actin filaments; leads to tropomyosin being physically moved aside to uncover cross-bridge binding sites on actin.



Tropomyosin  
Troponin  
 $\text{Ca}^{2+}$   
Actin  
Cross-bridge binding site  
Myosin cross bridge



***David Bolinsky, XVIVO***  
***Rocky Hill, CT***  
**<http://www.xvivo.net/>**



**muscleanimation.mov**

**<http://www.youtube.com/watch?v=BMT4PtXRCVA>**

**<http://www.vetmed.wsu.edu/van308/muscleanimation.htm>**

**[http://highered.mcgraw-hill.com/sites/0072495855/student\\_view0/chapter10/animation\\_action\\_potentials\\_and\\_muscle\\_contraction.html](http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter10/animation_action_potentials_and_muscle_contraction.html)**

***A. Malcolm Campbell***

***Davidson College, Davidson, NC***

***[www.bio.davidson.edu/courses/movies.html](http://www.bio.davidson.edu/courses/movies.html)***

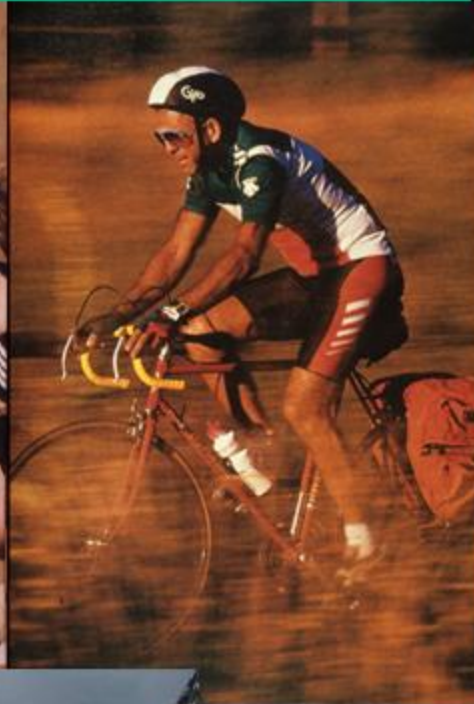
***<http://www.bio.davidson.edu/misc/movies/musclcp.mov>***



**Musclcp.mov**

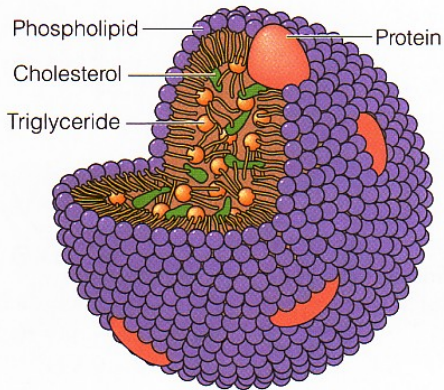
# Adaptations to Exercise?

Mode, Intensity, Duration, Frequency,  
Distribution of Training Sessions?  
Conditions of Environment? Individual?



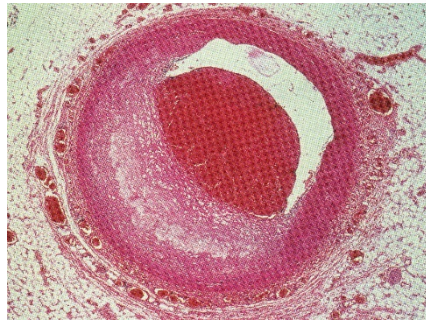
# Adaptations to Exercise?

Body Levels of Organization?  
Which Body System?

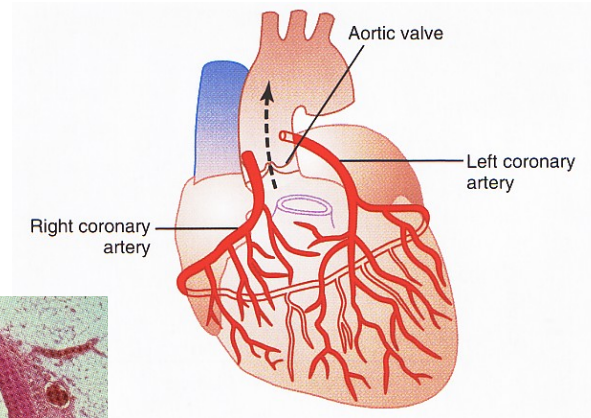


A typical lipoprotein

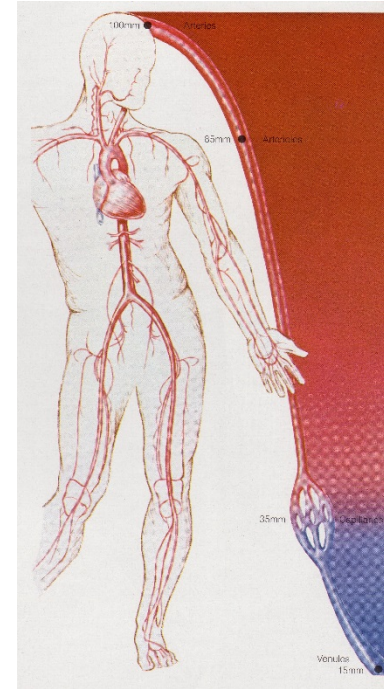
**Molecular**



**Cell/Tissue**

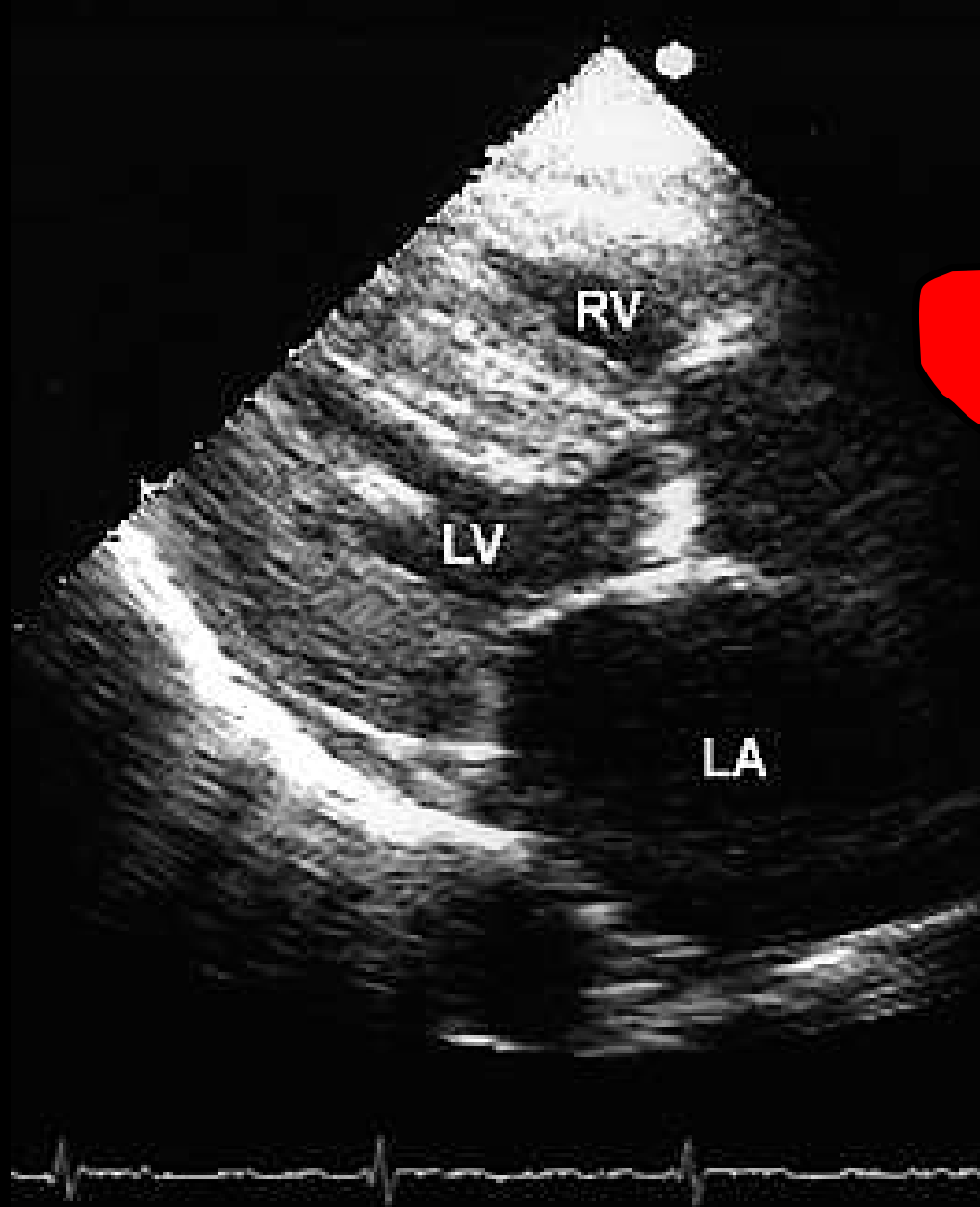


**Organ**

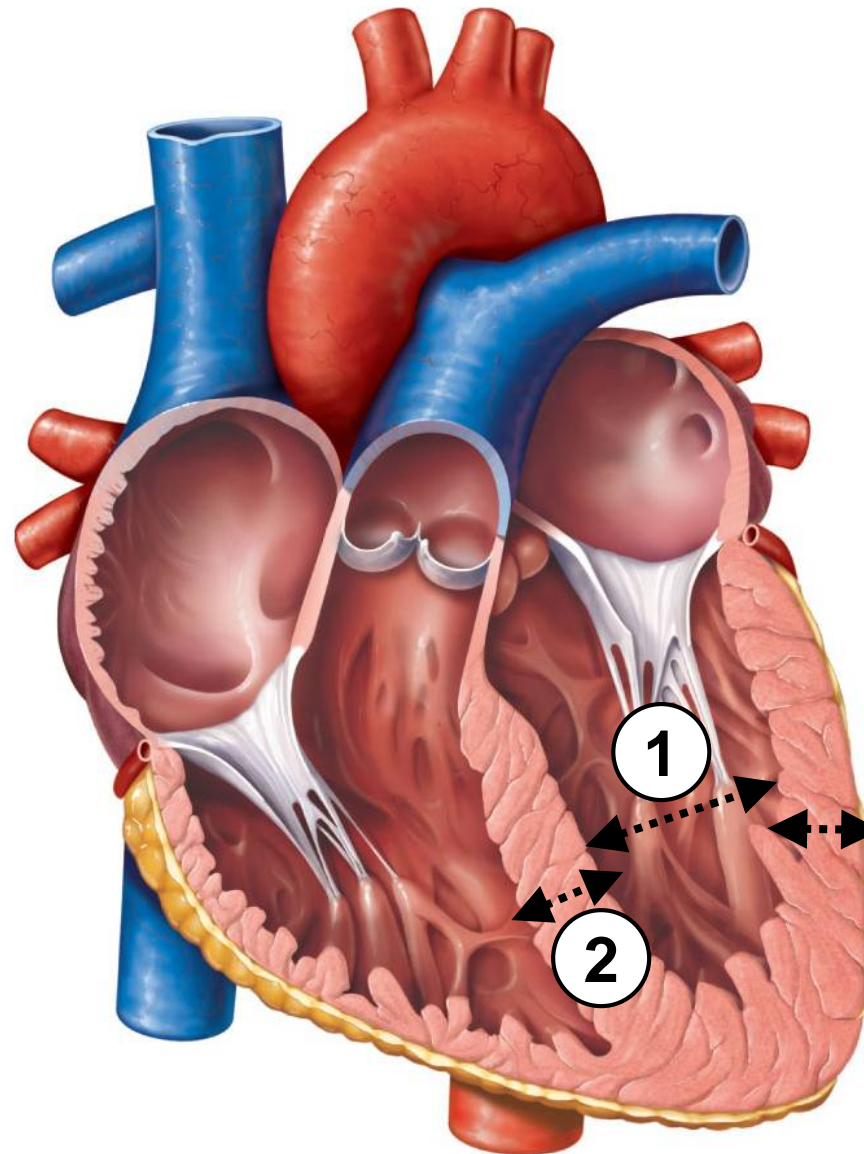


**Body System**

# *Echocardiography documents hypertrophy...*



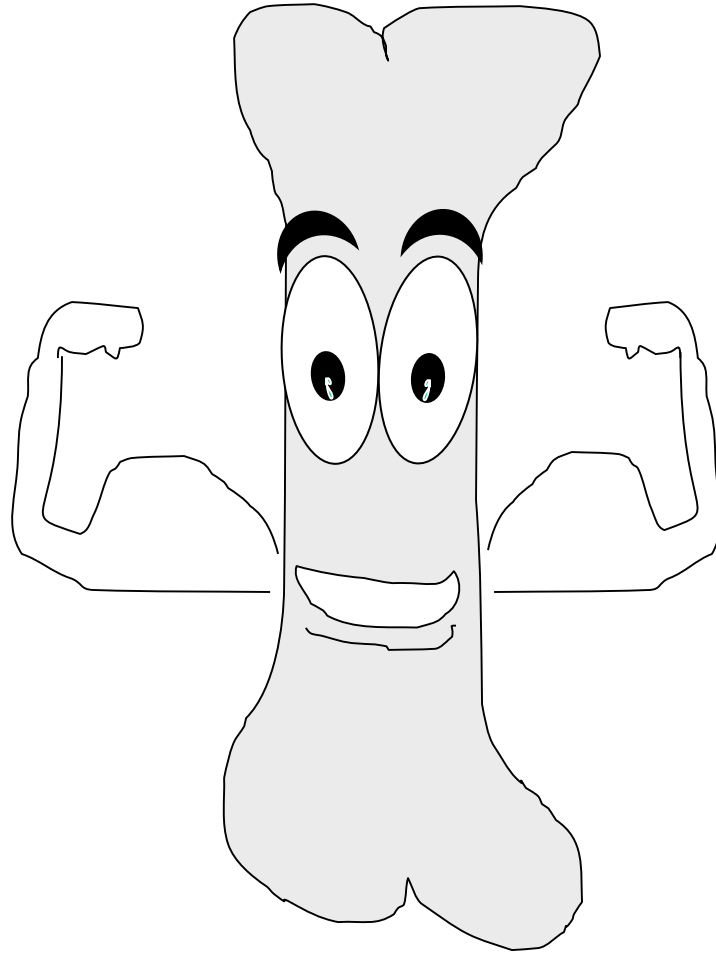
# **Cardiac Adaptations to Exercise:** **① Endurance vs. ② Strength Training**



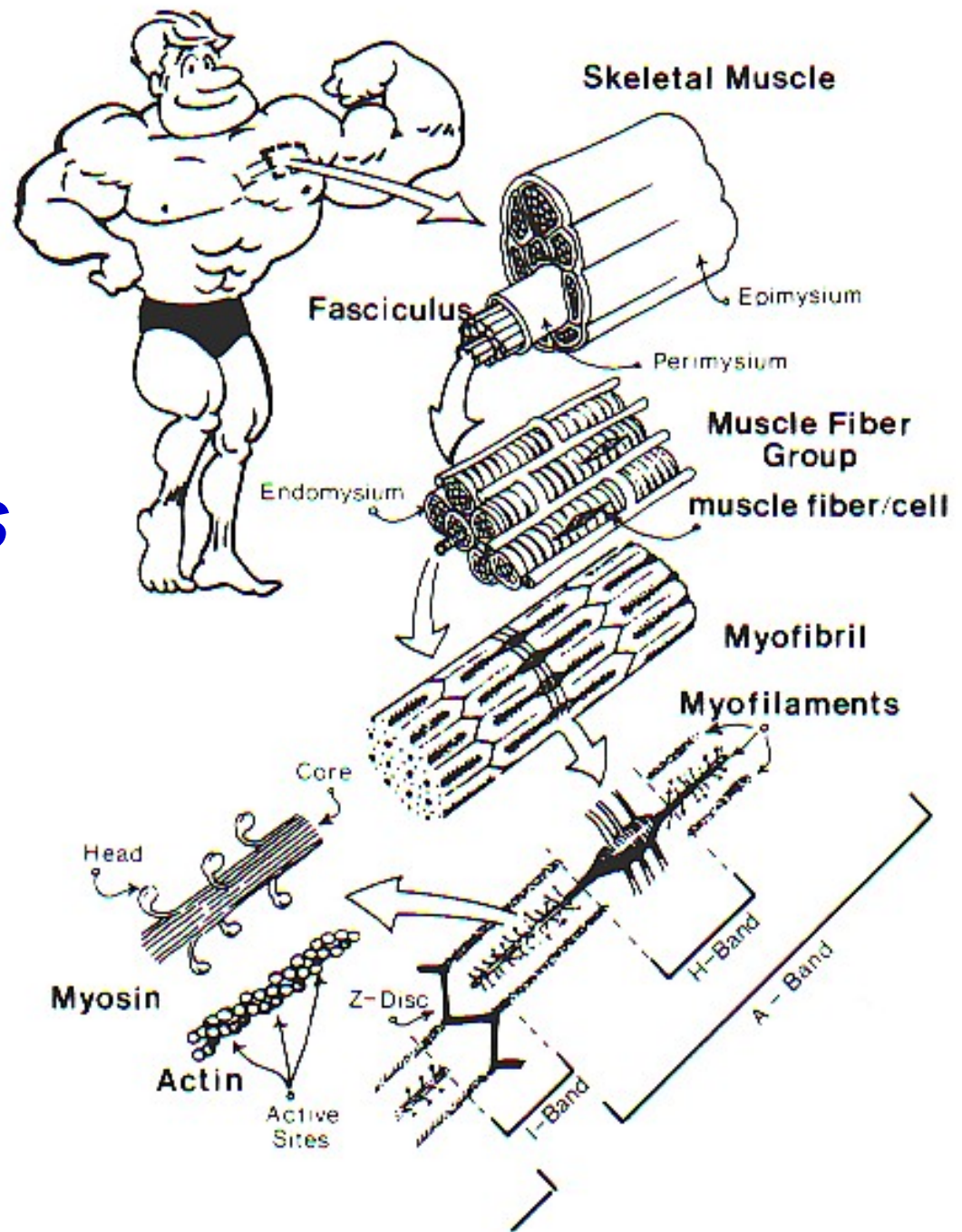
**NB: ① > ↑ LBM**

**① + ②**

***As muscles tug on bones, bones get stronger, too!...many systems adapt!!***



# ***Muscle Adaptations to Exercise***







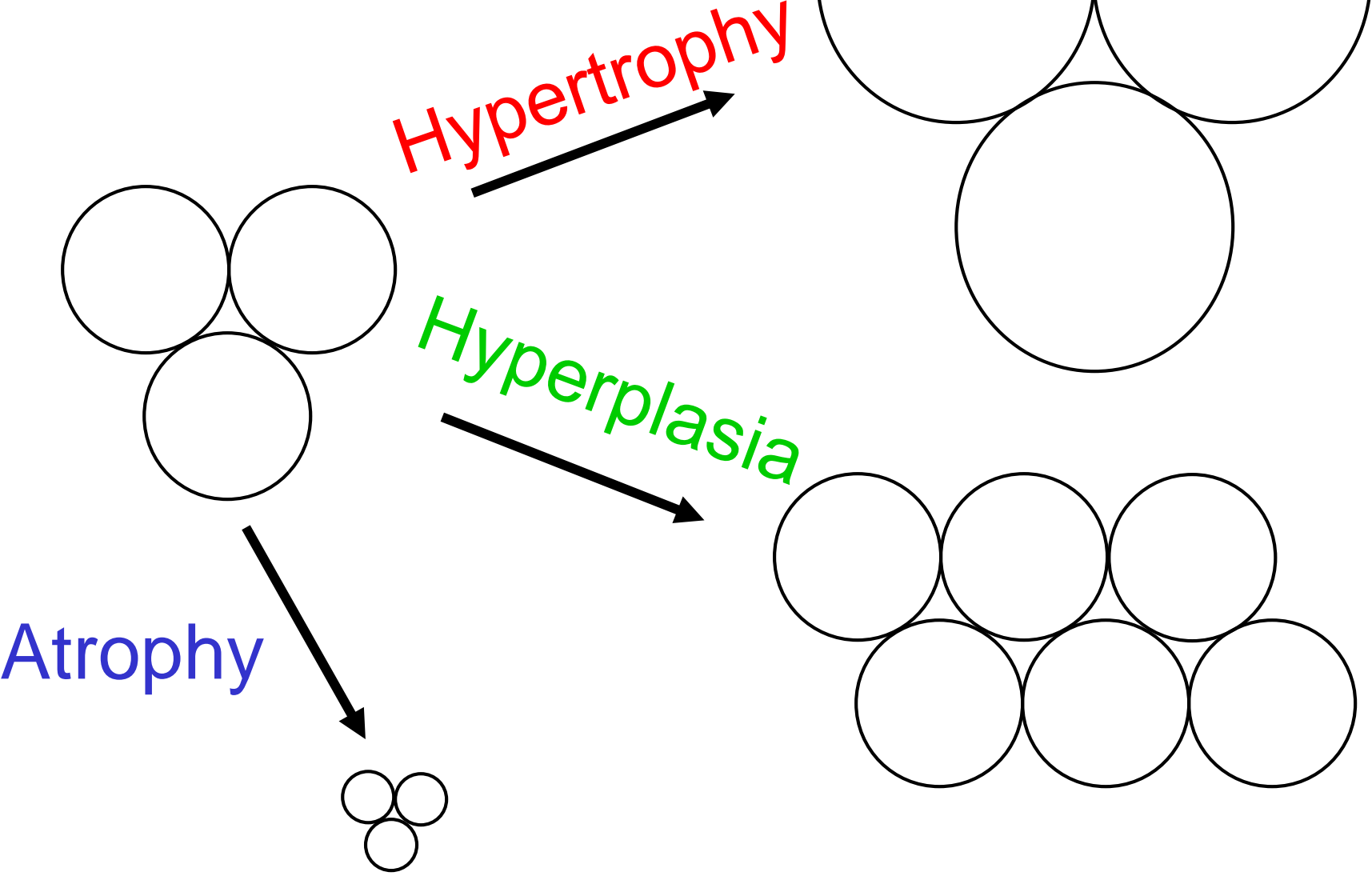
## Atrophy

*decrease in size  
& strength*

## Hypertrophy

*increase in size  
& strength*

# *Skeletal Muscle*



# *Women & Hypertrophy?*



***What happens in muscles at cellular & subcellular levels?***





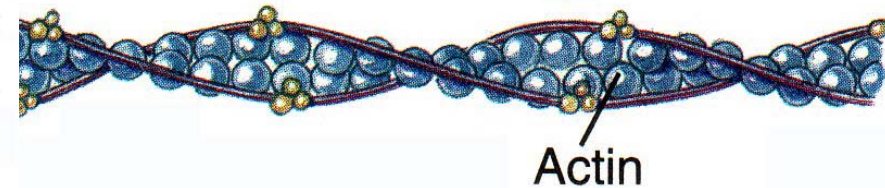
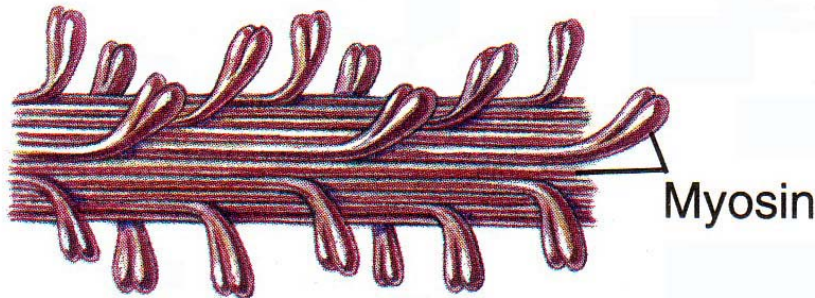
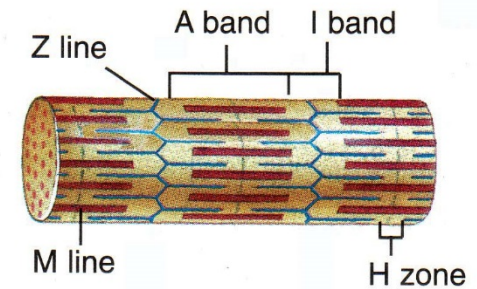
Myofibril

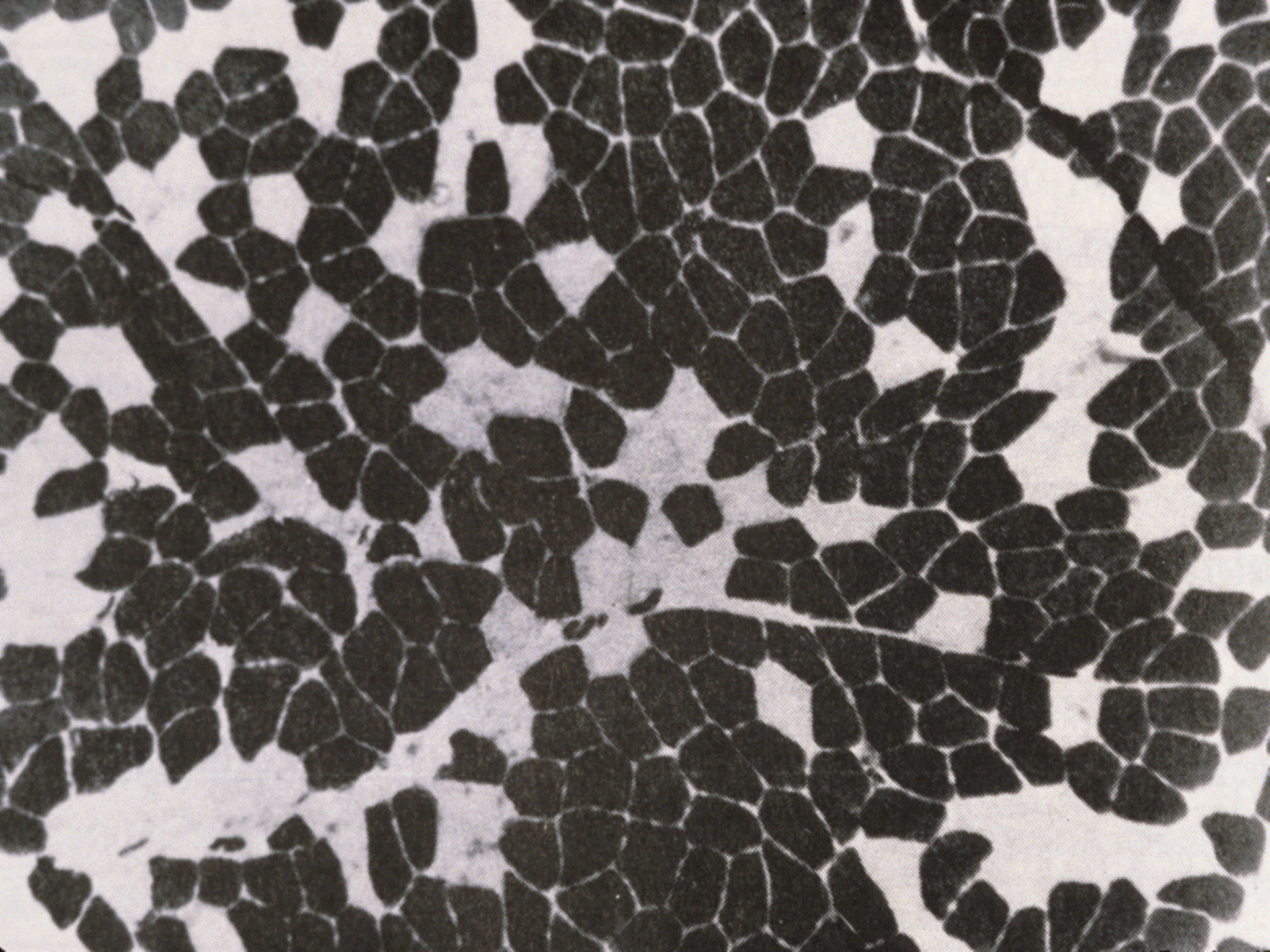
**Hypertrophy: *Increased***

***Number of Myofibrils***

***Thick & Thin Filaments***

***Myosin & Actin Molecules***





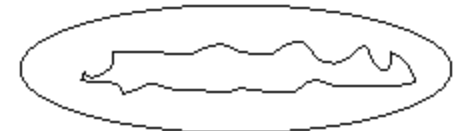
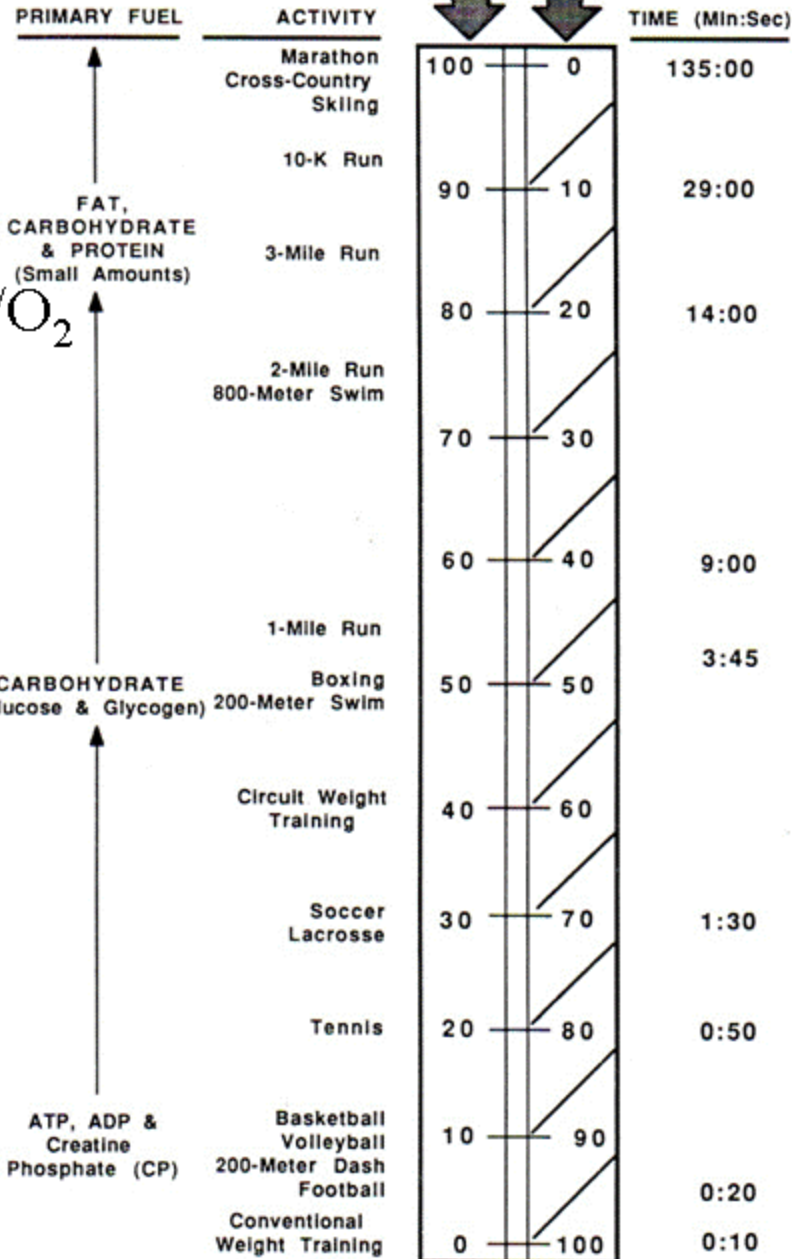
# Characteristics of Skeletal Muscle Fibers

Characteristic	TYPE OF FIBER		
	Slow Oxidative (Type I)	Fast Oxidative (Type IIa)	Fast Glycolytic (Type IIb)
Myosin-ATPase Activity	Low	High	High
Speed of Contraction	Slow	Fast	Fast
Resistance to Fatigue	High	Intermediate	Low
Aerobic Capacity	High	High	Low
Anaerobic Capacity	Low	Intermediate	High
Mitochondria	Many	Many	Few
Capillaries	Many	Many	Few
Myoglobin Content	High	High	Low
Color of Fibers	Red	Red	White
Glycogen Content	Low	Intermediate	High



**AEROBIC**

w/O<sub>2</sub>



**MITOCHONDRIA**

**CYTOSOL**

Glycolysis



Immediate/ATP-PC



**ANAEROBIC**



# *Changes in Muscle Due to Strength Training*

- ↑ Size of larger fast vs smaller slow fibers
- ↑ CP as well as creatine phosphokinase (CPK) which enhances short-term power output
- ↑ Key enzymes which help store and dissolve sugar including glycogen phosphorylase (GPP) & phosphofructokinase (PFK)
- ↓ Mitochondrial # relative to muscle tissue
- ↓ Vascularization relative to muscle tissue
- ↑ Splitting of fast fibers? Hyperplasia?  
With growth hormone (GH), androgenic-anabolic steroids (AAS)?

# *Changes in Muscle Due to Endurance Training*

- ↑ Mitochondria, # & size
- ↑ Mitochondrial (aerobic) enzymes including those specific for fat burning
- ↑ Vascularization of muscles (better blood flow)
- ↑ Stores of fat in muscles accompanied by
- ↓ Triglycerides/fats in bloodstream
- ↑ Enzymes: activation, transport, breakdown ( $\beta$ -oxidation) of fatty acids
- ↑ Myoglobin (enhances O<sub>2</sub> transport)
- ↑ Resting energy levels which inhibit sugar breakdown
- ↑ Aerobic capacity of all three fiber types.

***Which end of  
continuum?***

**+**

***Which energy  
nutrient/s?***

# **+ Which specific muscles?**





cf:





***Dancing can be super aerobic exercise, too,  
& you don't have to be a star!***



# Extremes of the energy continuum!

