

BI 121 Lecture 12 **Thanks for your help with the blood chemistry lab!...** 

- I. Announcements Optional notebook check + Lab 6 tomorrow. Pulmonary Function Testing. Final exam > your Q on Wed. Q?
- II. Autonomic Nervous System Overview LS pp 178 – 85  
LS Table 7-1 p 183 + stories to remember **fight-or-flight!**
- III. Neuromuscular Connections LS ch 7 pp 186-92, DC pp 69-71  
How does the signal cross the nerve-muscle gap? LS fig 7-5
  - A. Normal function?  $Ca^{2+}$  for bones!...but what else? LS p 190
  - B. What do black widow spider venom, botulism, curare & nerve gas have in common? Botox? LS p 189-91
- IV. Muscle Structure, Function & Adaptation LS ch 8, DC Module 12
  - A. Muscle types: cardiac, smooth, skeletal LS fig 8-1 p 194-6
  - B. How is skeletal muscle organized? LS fig 8-2, DC fig 12-2
  - C. What do thick filaments look like? LS fig 8-4, DC fig 12-4
  - D. How about thin filaments? LS fig 8-5
  - E. Banding pattern? LS fig 8-3, fig 8-7
  - F. How do muscles contract? LS fig 8-6, 8-10
  - G. What's a cross-bridge cycle? LS fig 8-11 +...
  - H. Summary of skeletal muscle contraction
    - I. Exercise adaptation variables: **mode, intensity, duration, frequency, distribution, individual & environmental char...?**
  - J. Endurance vs. strength training continuum? fiber types...

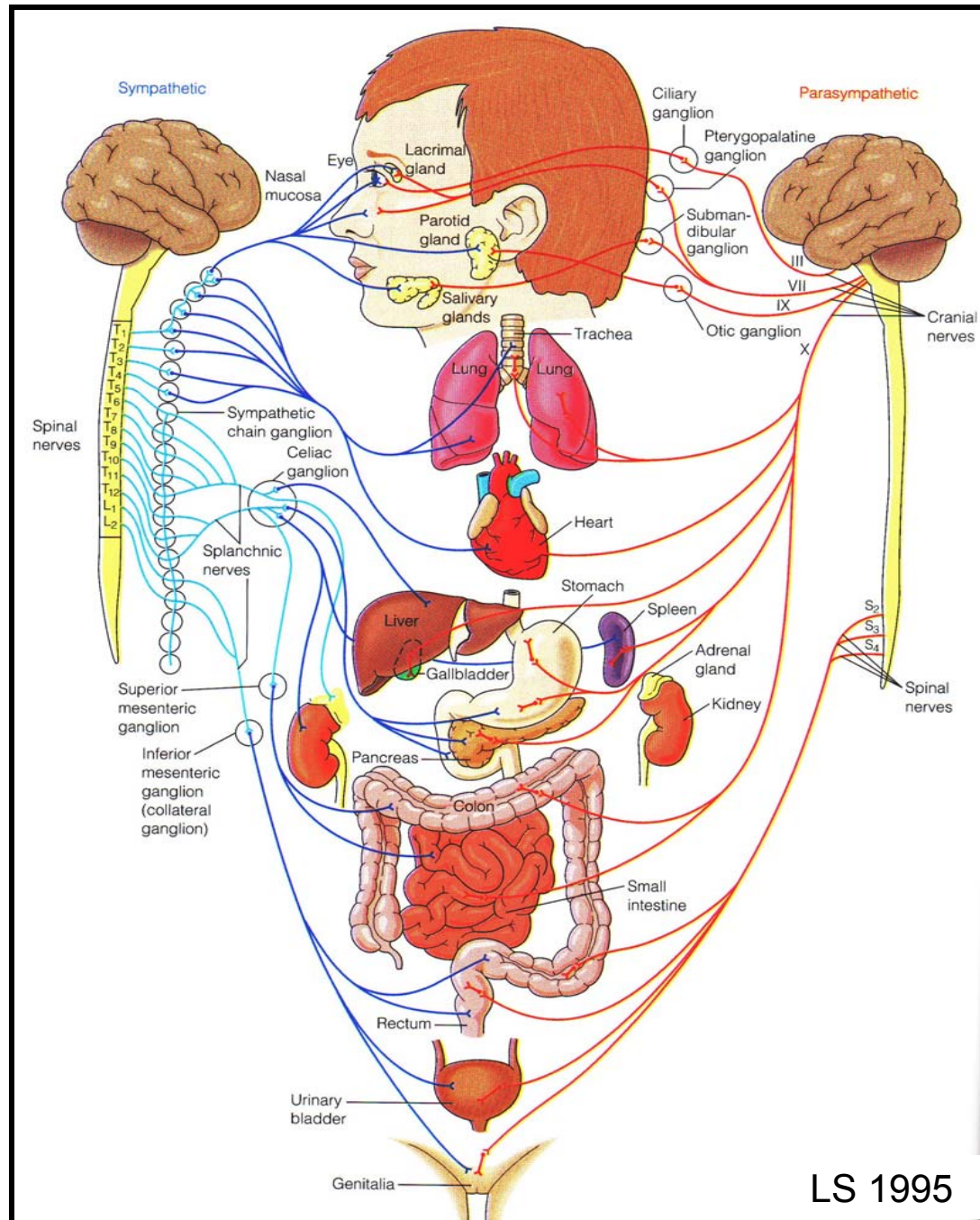


# Autonomic Nervous System

Why overlap or dual innervation?

*Fine-tune control & safety!*

cf: LS 2012 fig 7-3



LS 1995

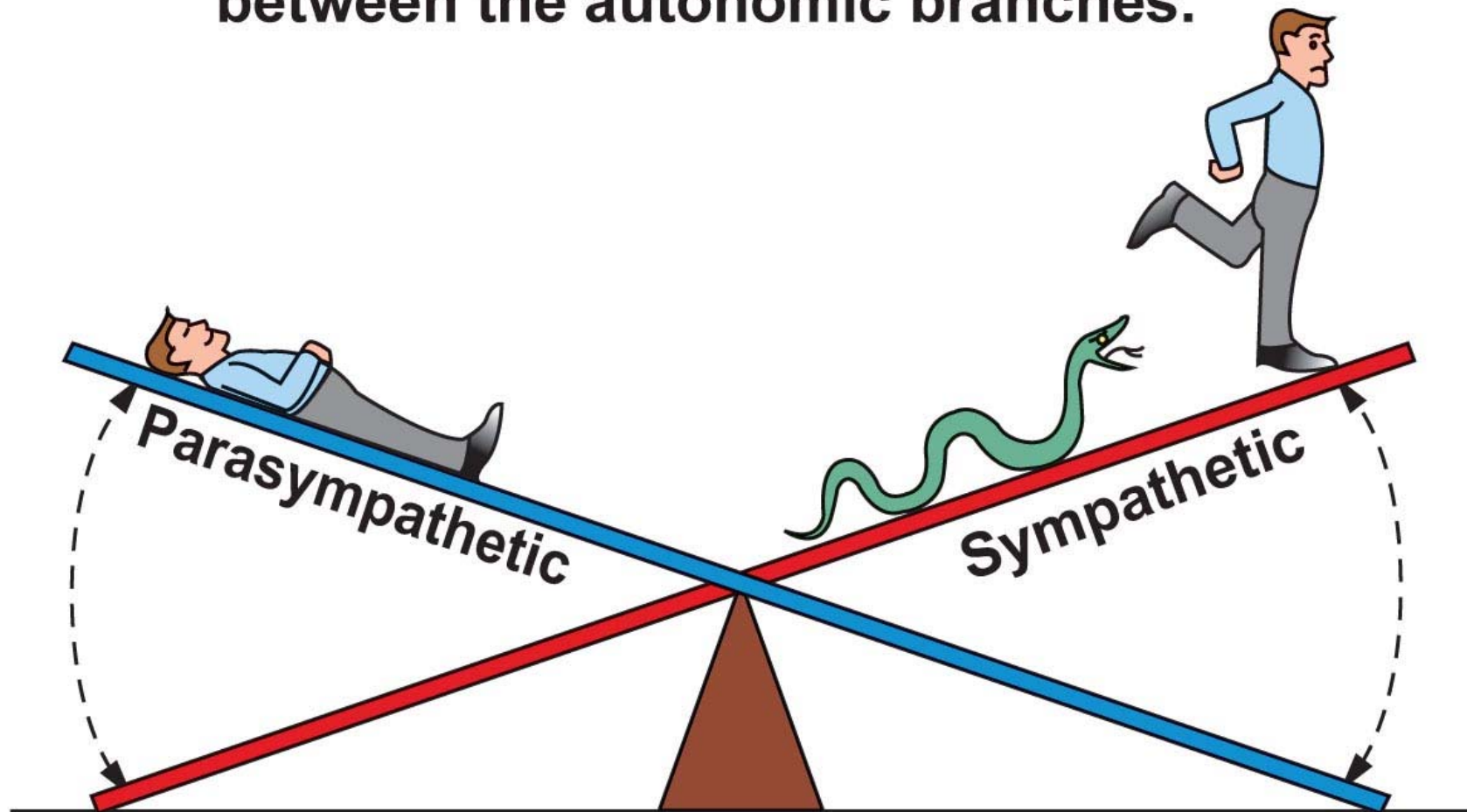
PARASYMPATHETIC = RESTING, DIGESTIVE,  
HOUSEKEEPING FUNCTIONS



# FIGHT/FLIGHT/ALARM REACTION!!



Homeostasis is a dynamic balance between the autonomic branches.



**Rest-and-digest:  
Parasympathetic  
activity dominates.**

**Fight-or-flight:  
Sympathetic activity  
dominates.**





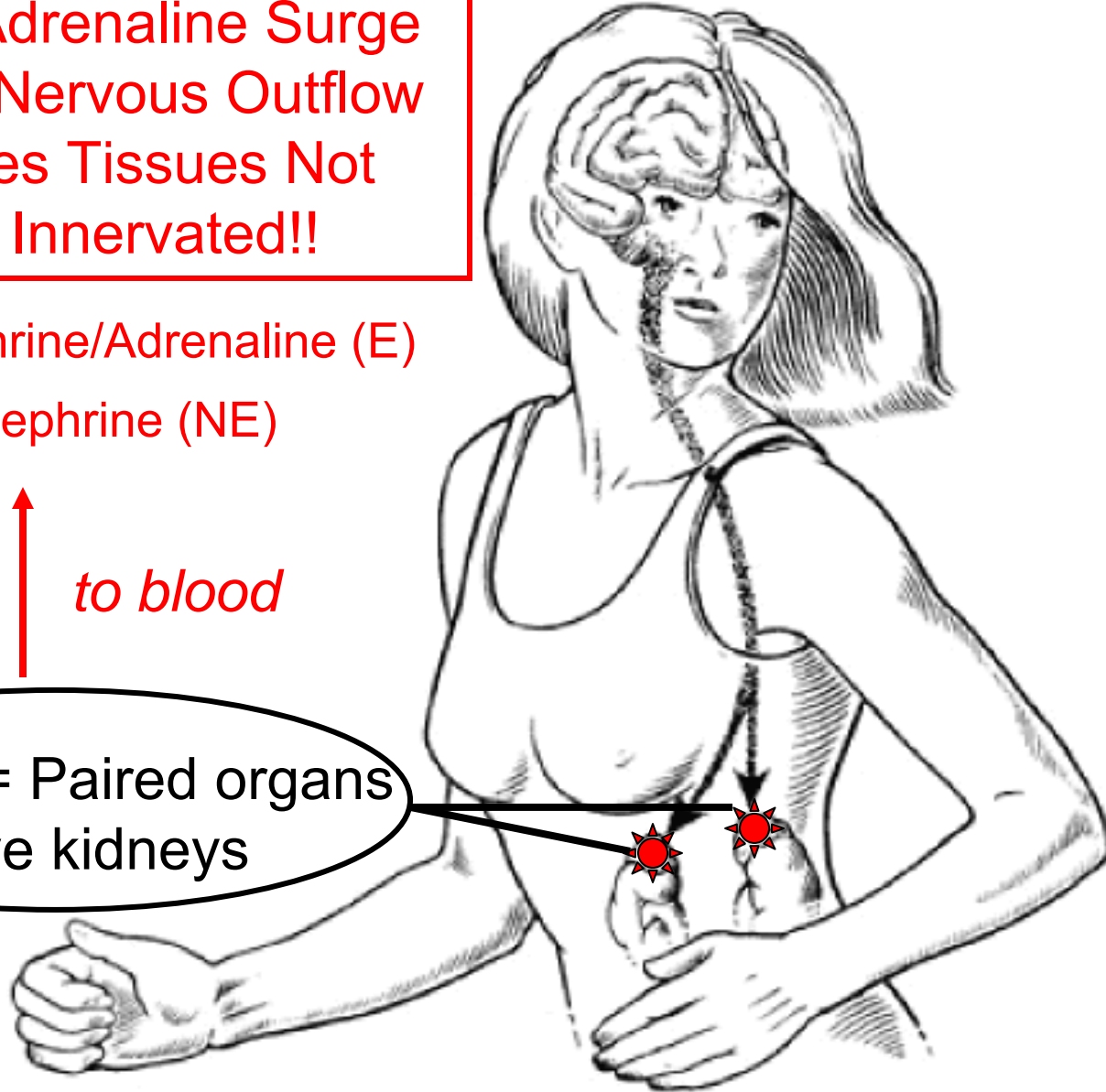
***Why adrenal  
activation &  
response  
important?***

Hormonal Adrenaline Surge  
Reinforces Nervous Outflow  
& Accesses Tissues Not  
Directly Innervated!!

80% Epinephrine/Adrenaline (E)  
20% Norepinephrine (NE)

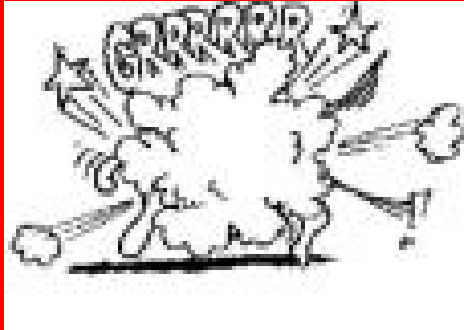
*Output* ↑ *to blood*

Adrenals = Paired organs  
above kidneys





# Fight-or-Flight Stories!



or

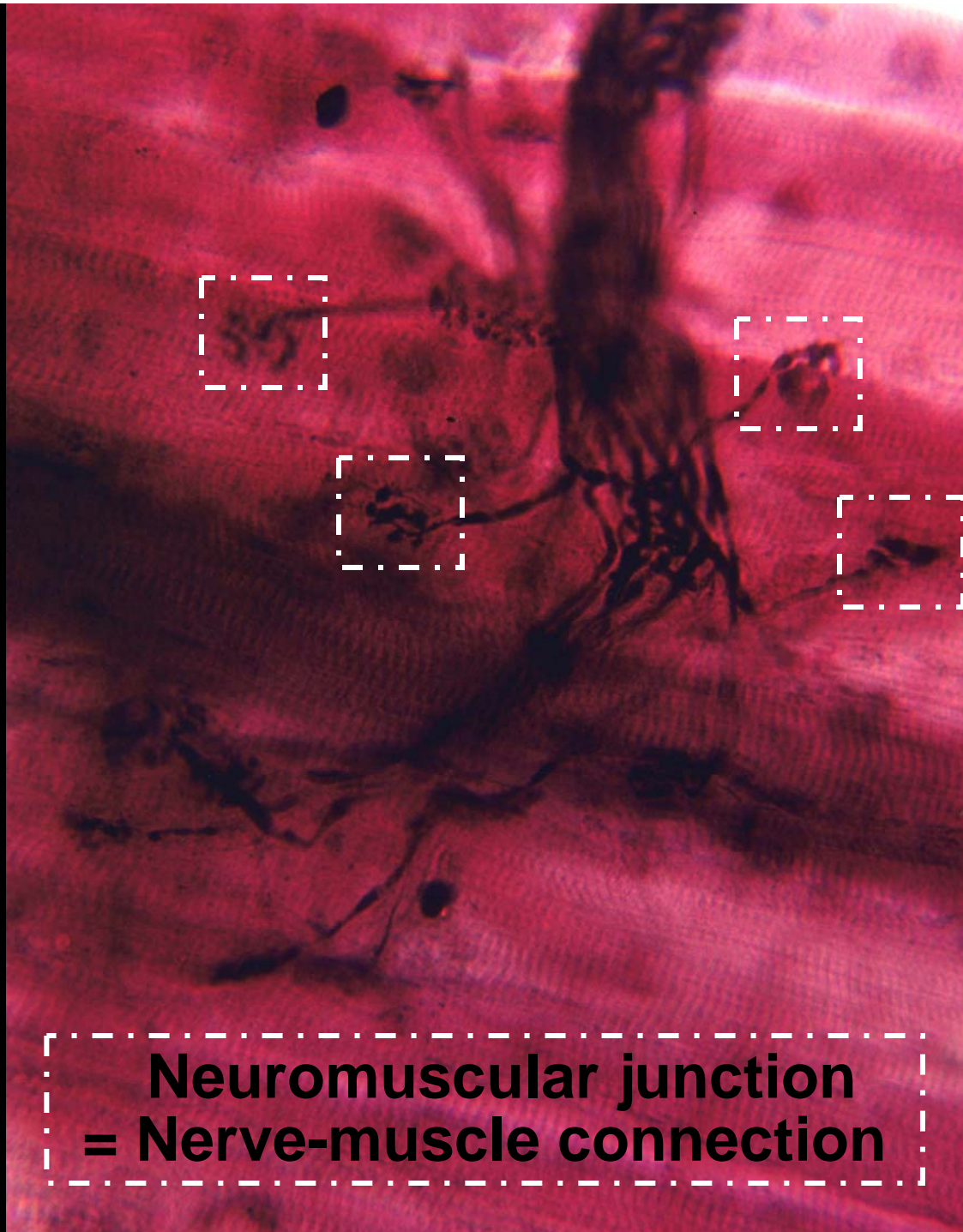


...choose this!!



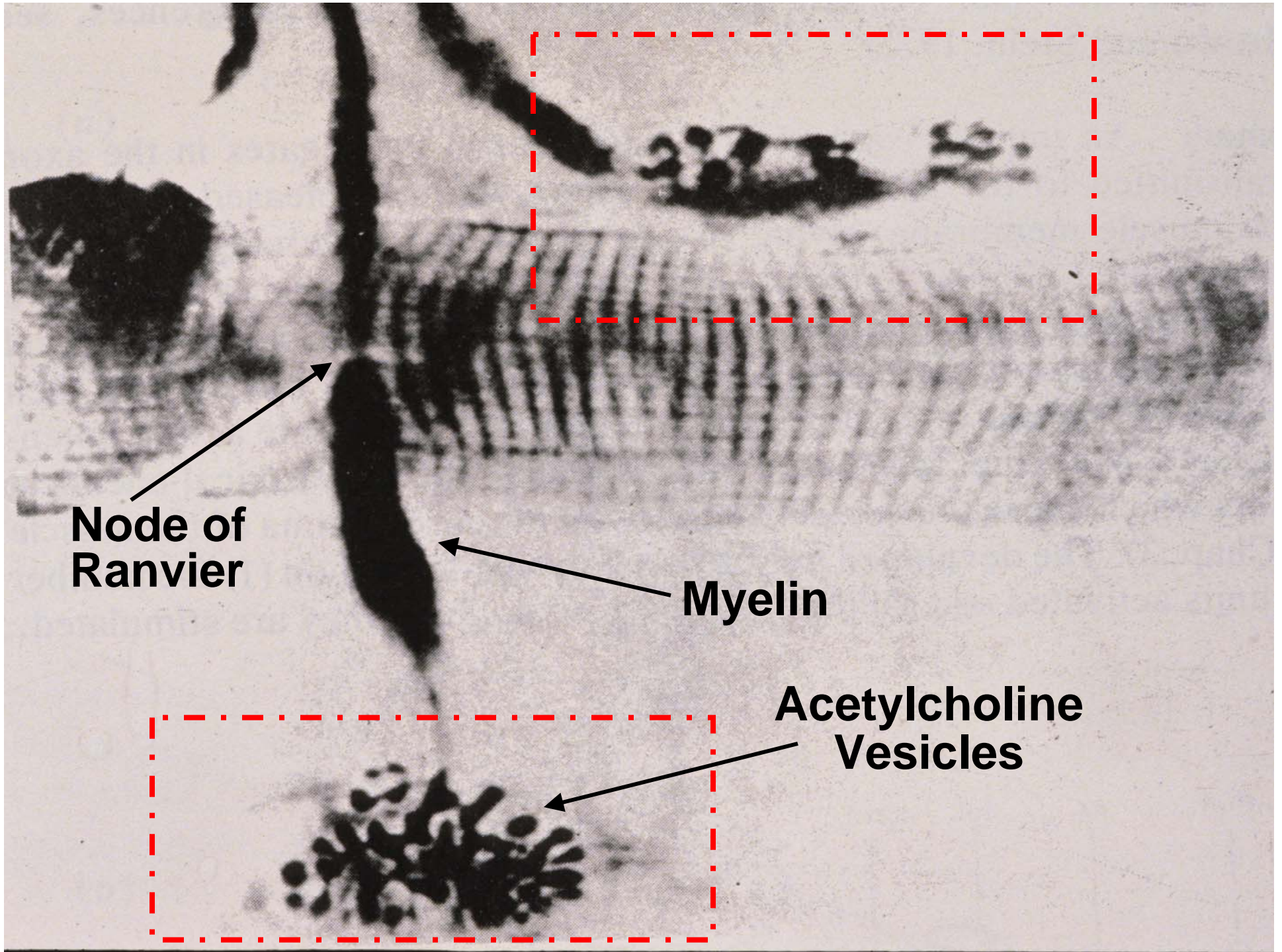
▲ **Table 7-1** Effects of Autonomic Nervous System on Various Organs

Organ	Effect of Sympathetic Stimulation	Effect of Parasympathetic Stimulation
<b>Heart</b>	Increases heart rate and increases force of contraction of the whole heart	Decreases heart rate and decreases force of contraction of the atria only
<b>Blood Vessels</b>	Constricts	Dilates vessels supplying the penis and the clitoris only
<b>Lungs</b>	Dilates the bronchioles (airways)	Constricts the bronchioles
<b>Digestive Tract</b>	Decreases motility (movement) Contracts sphincters (to prevent forward movement of tract contents) Inhibits digestive secretions	Increases motility Relaxes sphincters (to permit forward movement of tract contents) Stimulates digestive secretions
<b>Urinary Bladder</b>	Relaxes	Contracts (emptying)
<b>Eye</b>	Dilates the pupil Adjusts the eye for far vision	Constricts the pupil Adjusts the eye for near vision
<b>Liver (glycogen stores)</b>	Glycogenolysis (glucose is released)	None
<b>Adipose Cells (fat stores)</b>	Lipolysis (fatty acids are released)	None
<b>Exocrine Glands</b>		
<i>Exocrine pancreas</i>	Inhibits pancreatic exocrine secretion	Stimulates pancreatic exocrine secretion (important for digestion)
<i>Sweat glands</i>	Stimulates secretion by sweat glands important in cooling the body	Stimulates secretion by specialized sweat glands in the armpits and genital area
<i>Salivary glands</i>	Stimulates a small volume of thick saliva rich in mucus	Stimulates a large volume of watery saliva rich in enzymes
<b>Endocrine Glands</b>		
<i>Adrenal medulla</i>	Stimulates epinephrine and norepinephrine secretion	None
<i>Endocrine pancreas</i>	Inhibits insulin secretion	Stimulates insulin secretion
<b>Genitals</b>	Controls ejaculation (males) and orgasm contractions (both sexes)	Controls erection (penis in males and clitoris in females)
<b>Brain Activity</b>	Increases alertness	None



**Neuromuscular junction  
= Nerve-muscle connection**





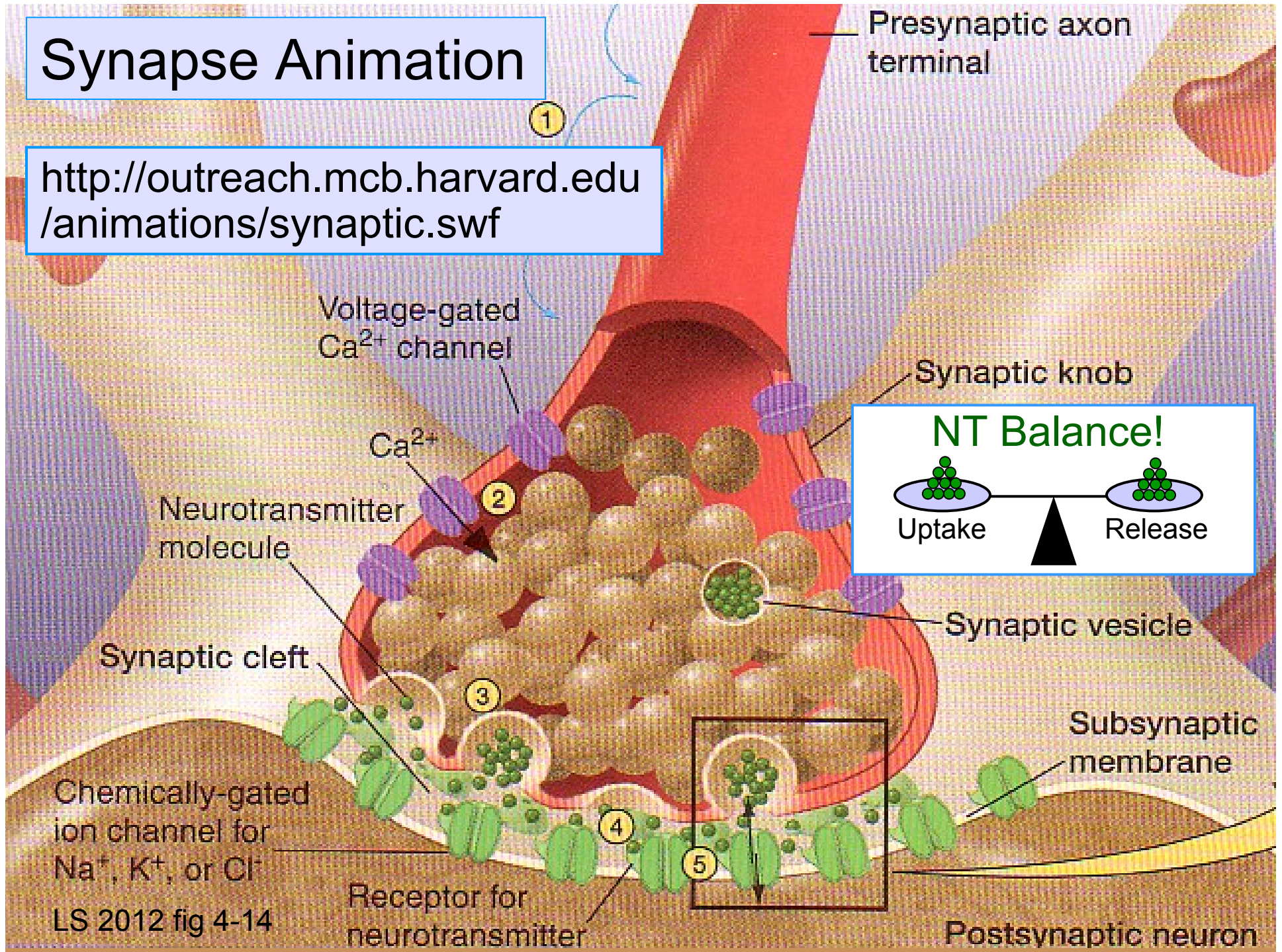
**Node of  
Ranvier**

**Myelin**

**Acetylcholine  
Vesicles**

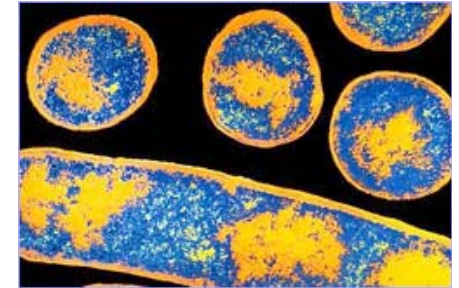
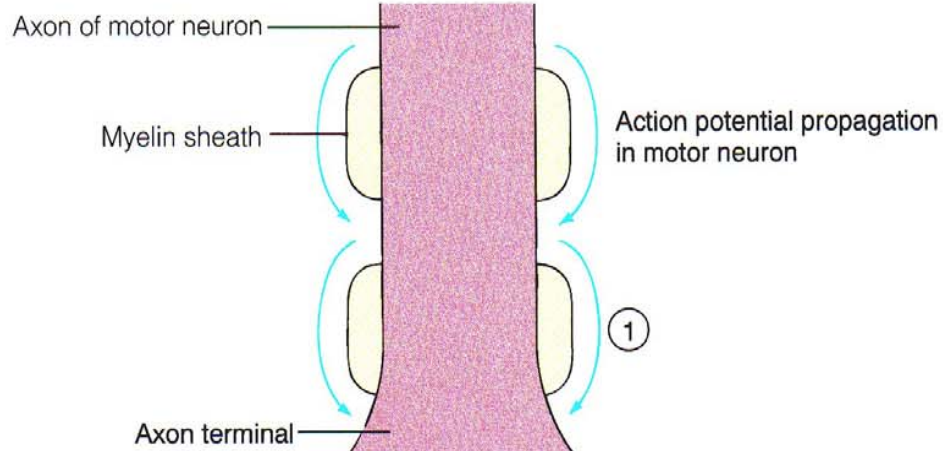
# Synapse Animation

<http://outreach.mcb.harvard.edu/animations/synaptic.swf>

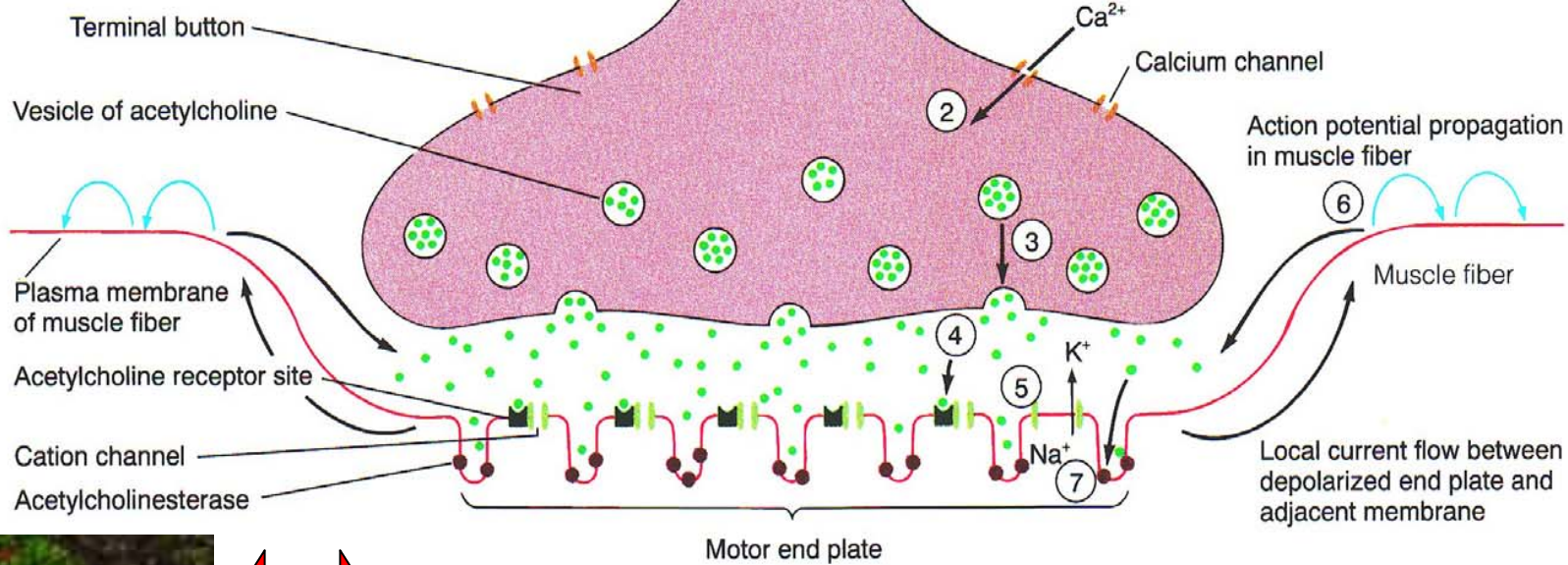




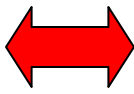
↑ 3



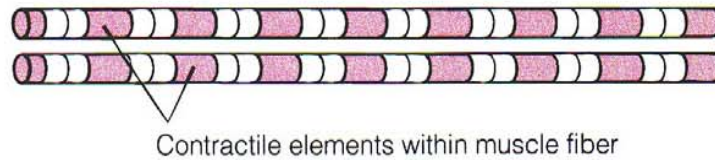
~~3~~



~~7~~



4





# Skeletal Muscles

## Homeostasis

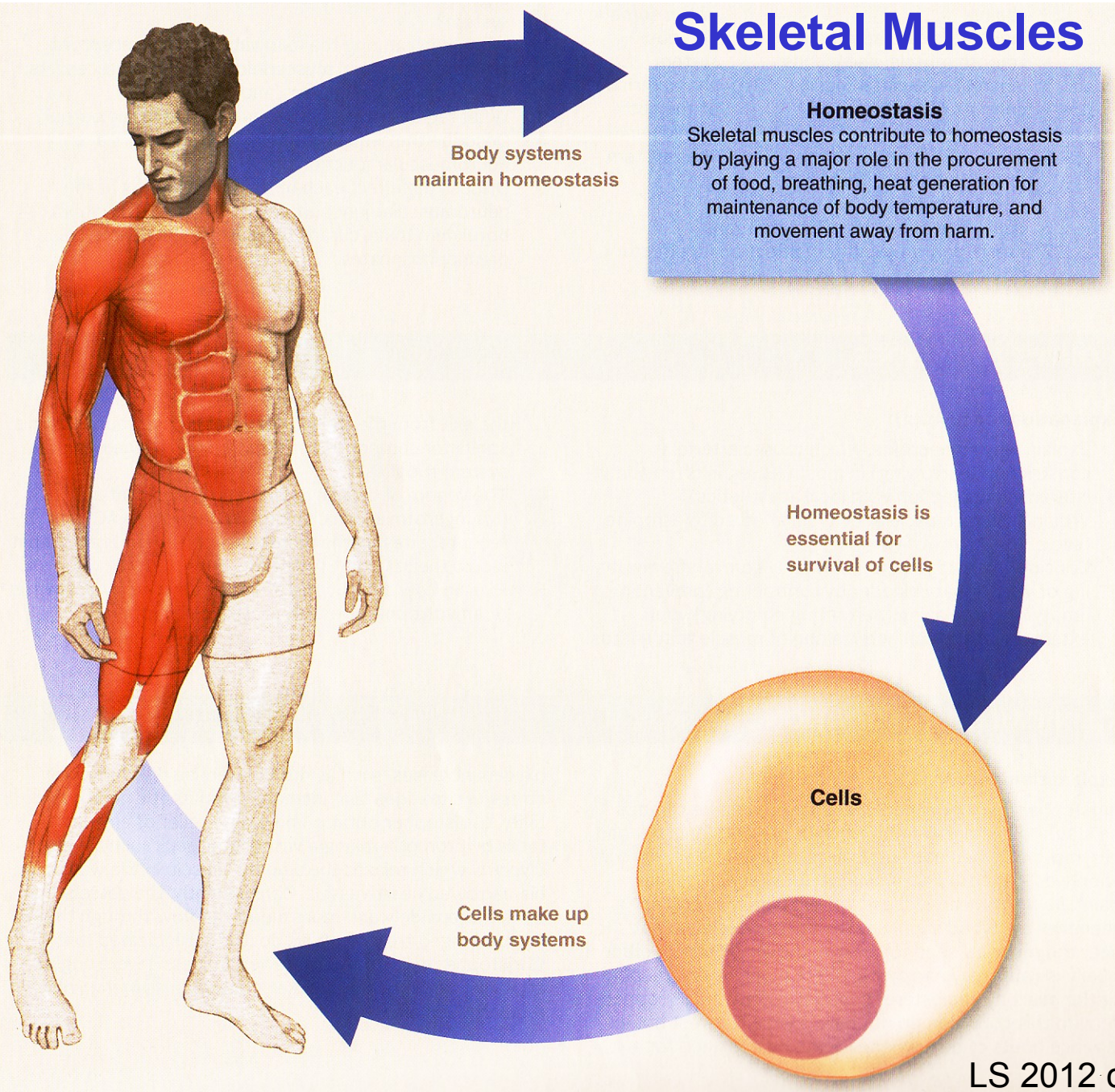
Skeletal muscles contribute to homeostasis by playing a major role in the procurement of food, breathing, heat generation for maintenance of body temperature, and movement away from harm.

Body systems  
maintain homeostasis

Homeostasis is  
essential for  
survival of cells

Cells

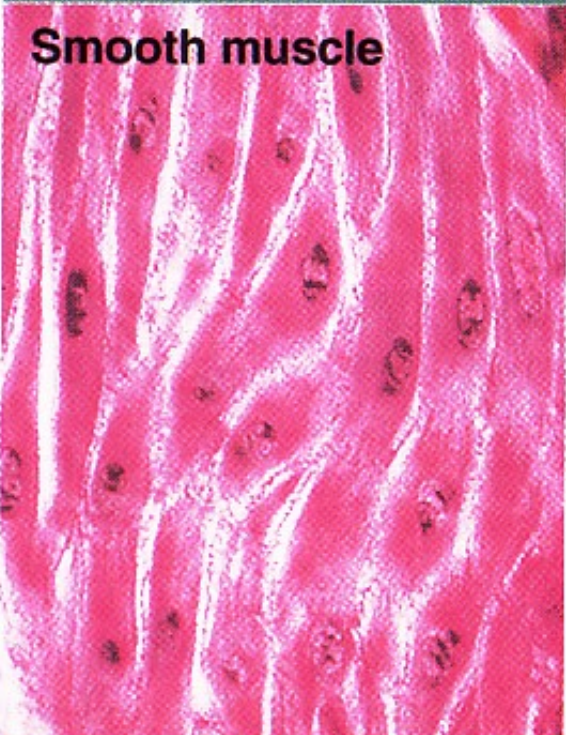
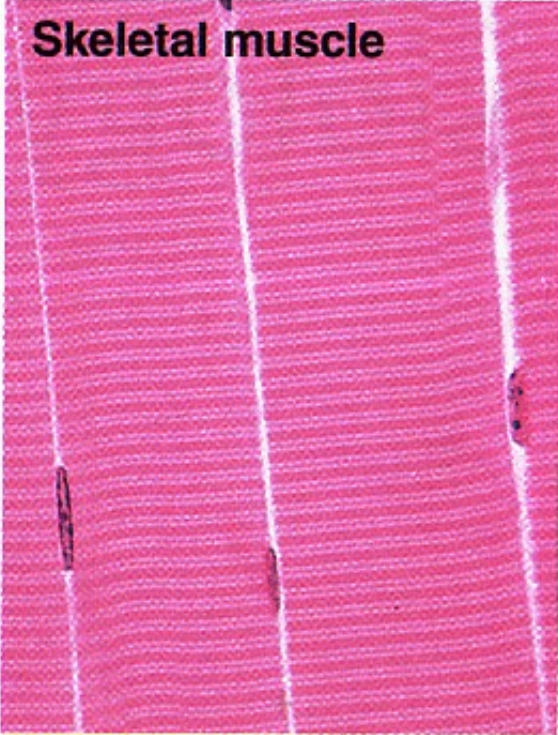
Cells make up  
body systems





Striated muscle

Unstriated muscle



Ed Reschke

Ed Reschke

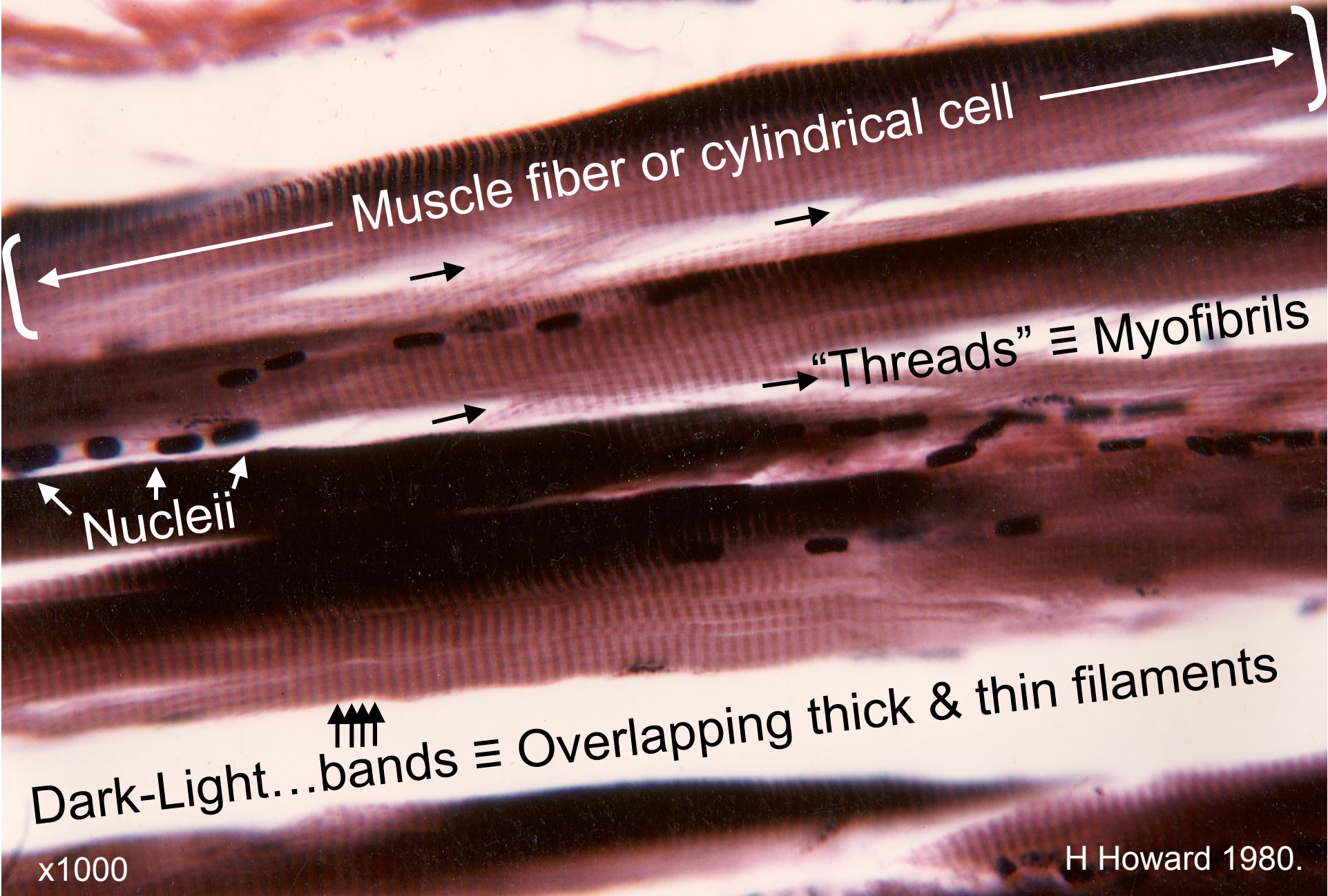
Biophoto/Photo Researchers, Inc.

Voluntary muscle

Involuntary muscle



# Skeletal Muscle Histology: Microscopic Anatomy



Muscle fiber or cylindrical cell

Nucleii

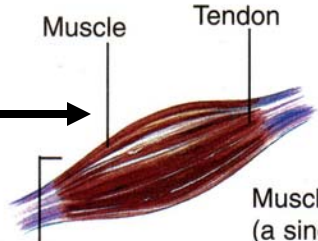
“Threads” ≡ Myofibrils

Dark-Light...bands ≡ Overlapping thick & thin filaments

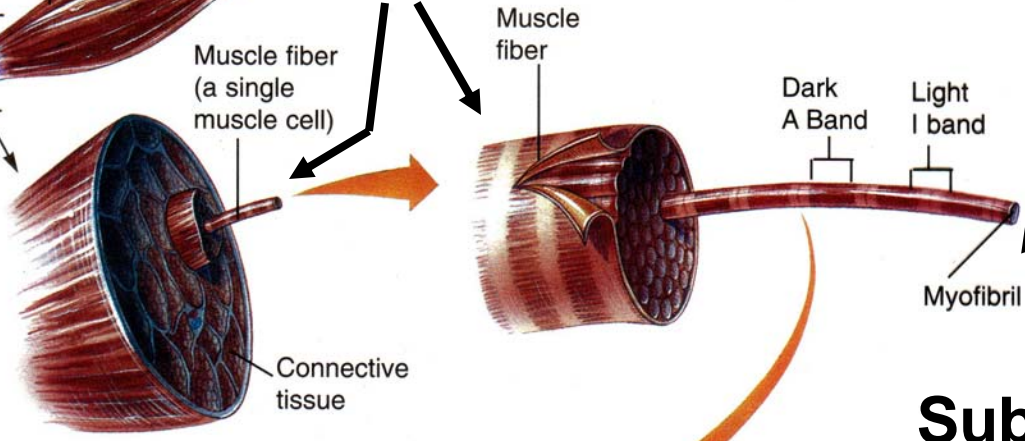
x1000

H Howard 1980.

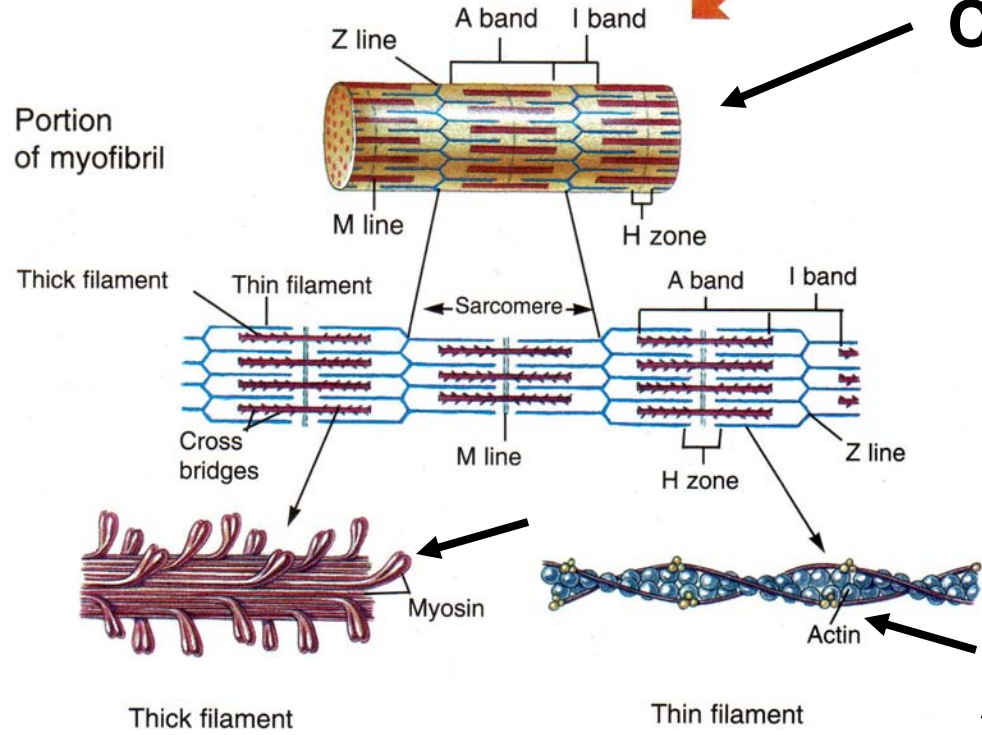
**Organ =  
Muscle**



**Cell = Myocyte = Fiber**



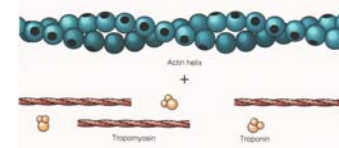
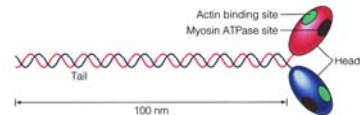
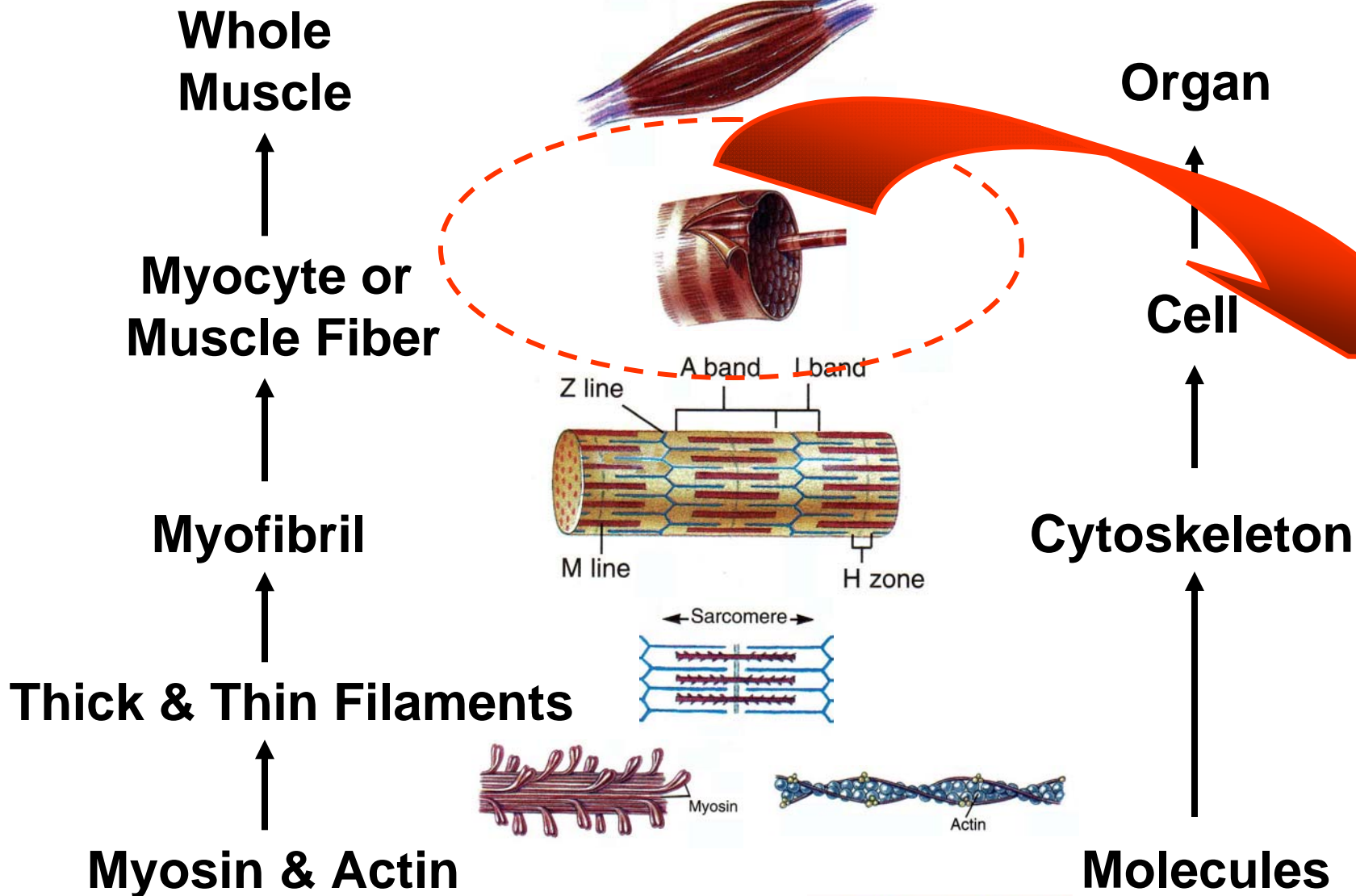
**Subcellular =  
Cytoskeleton**

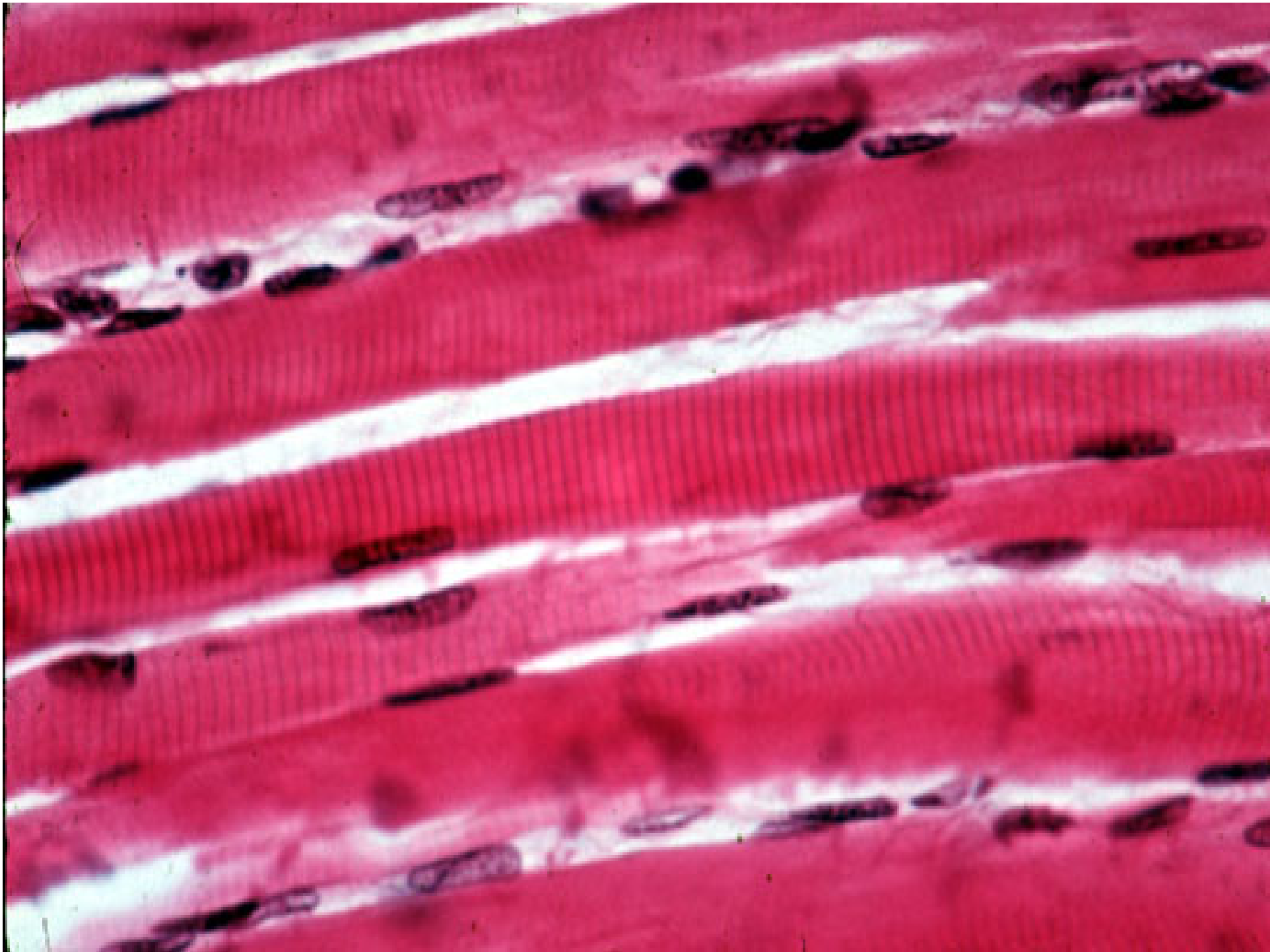


**Molecules =  
Actin & Myosin**

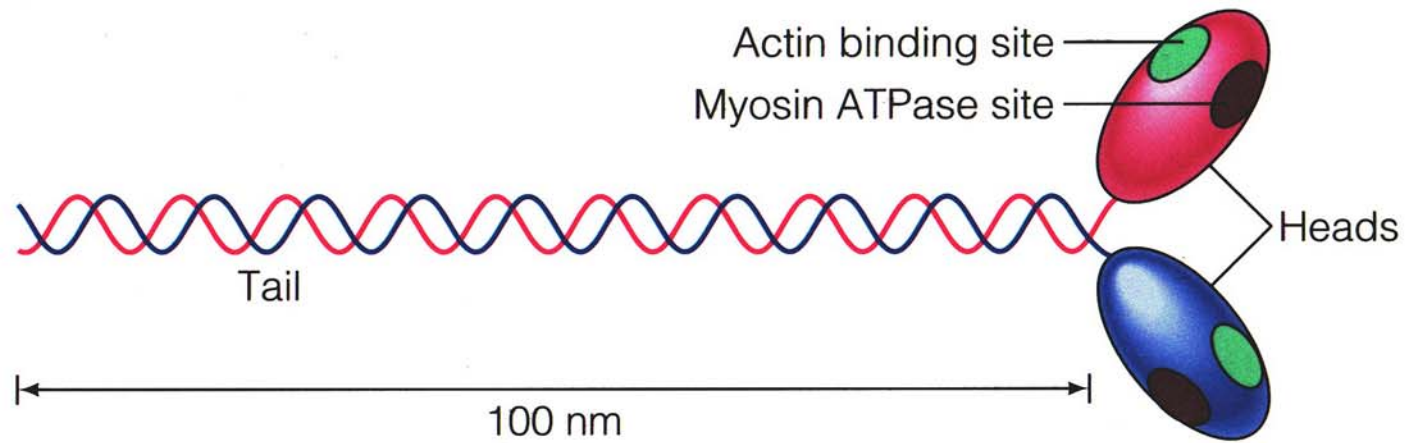
LS 2006, cf:  
LS 2012 fig 8-2





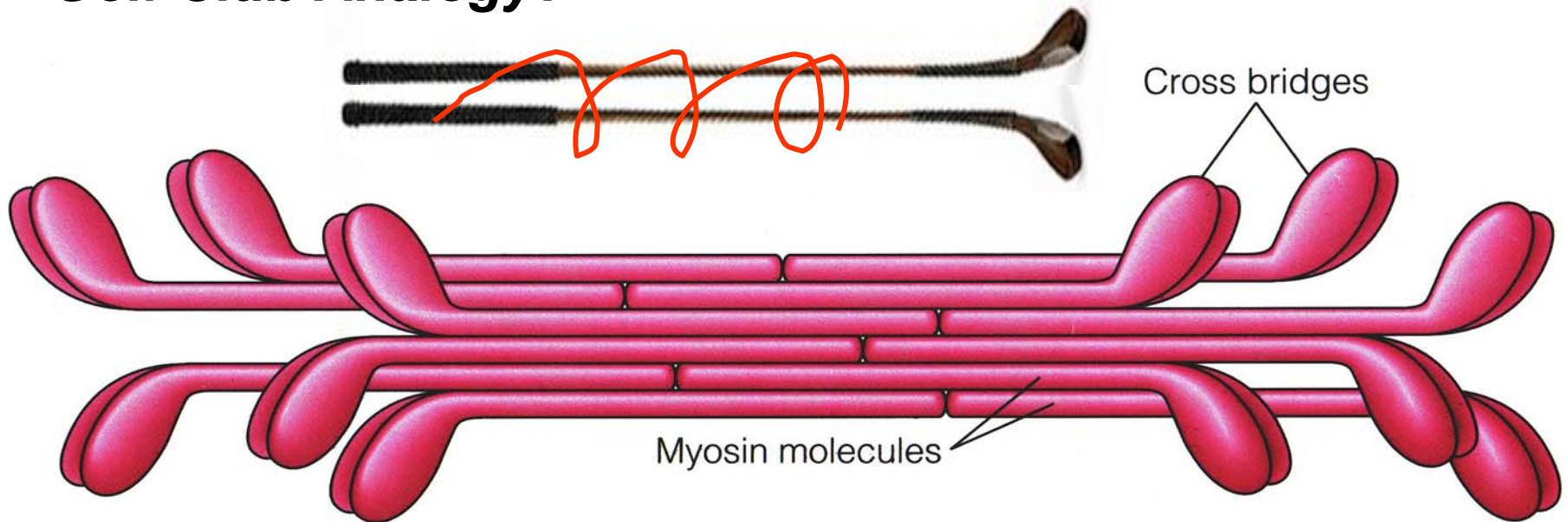






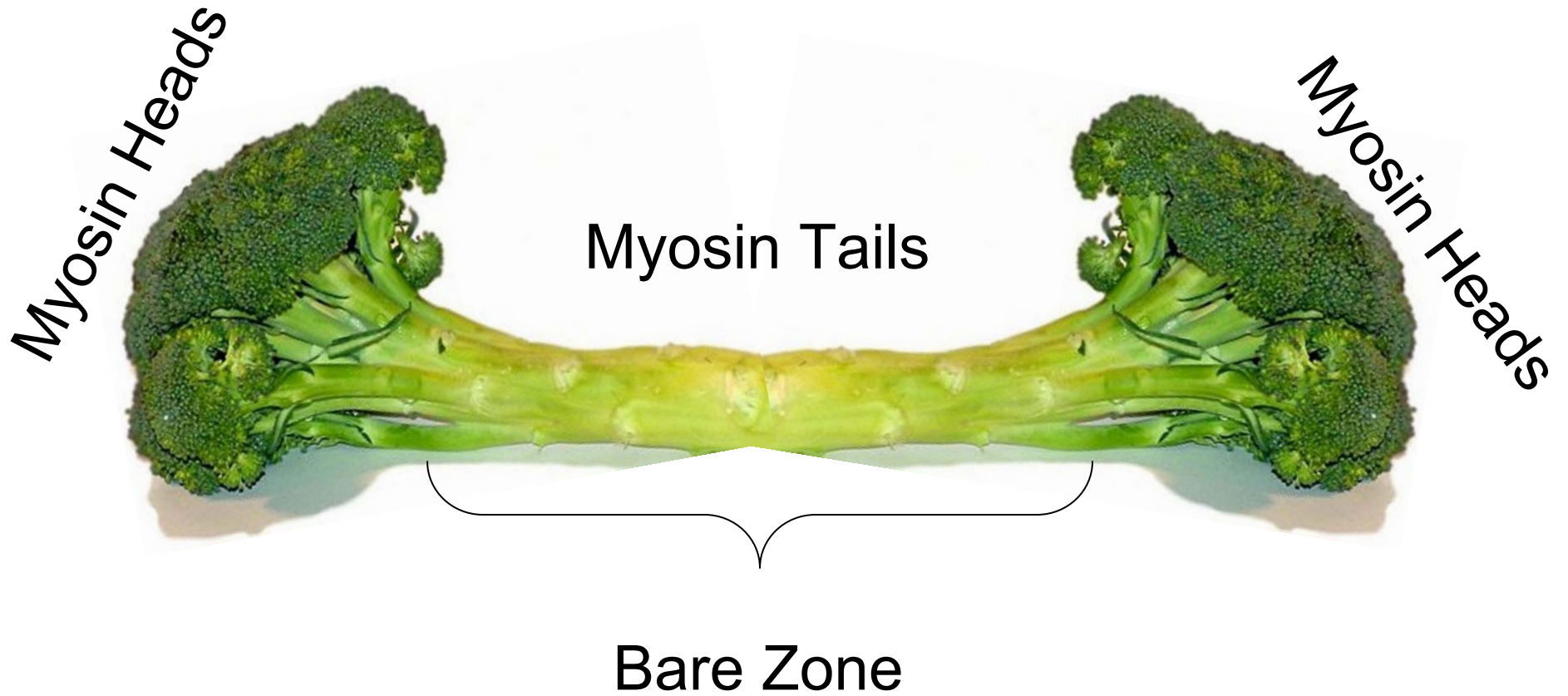
(a)

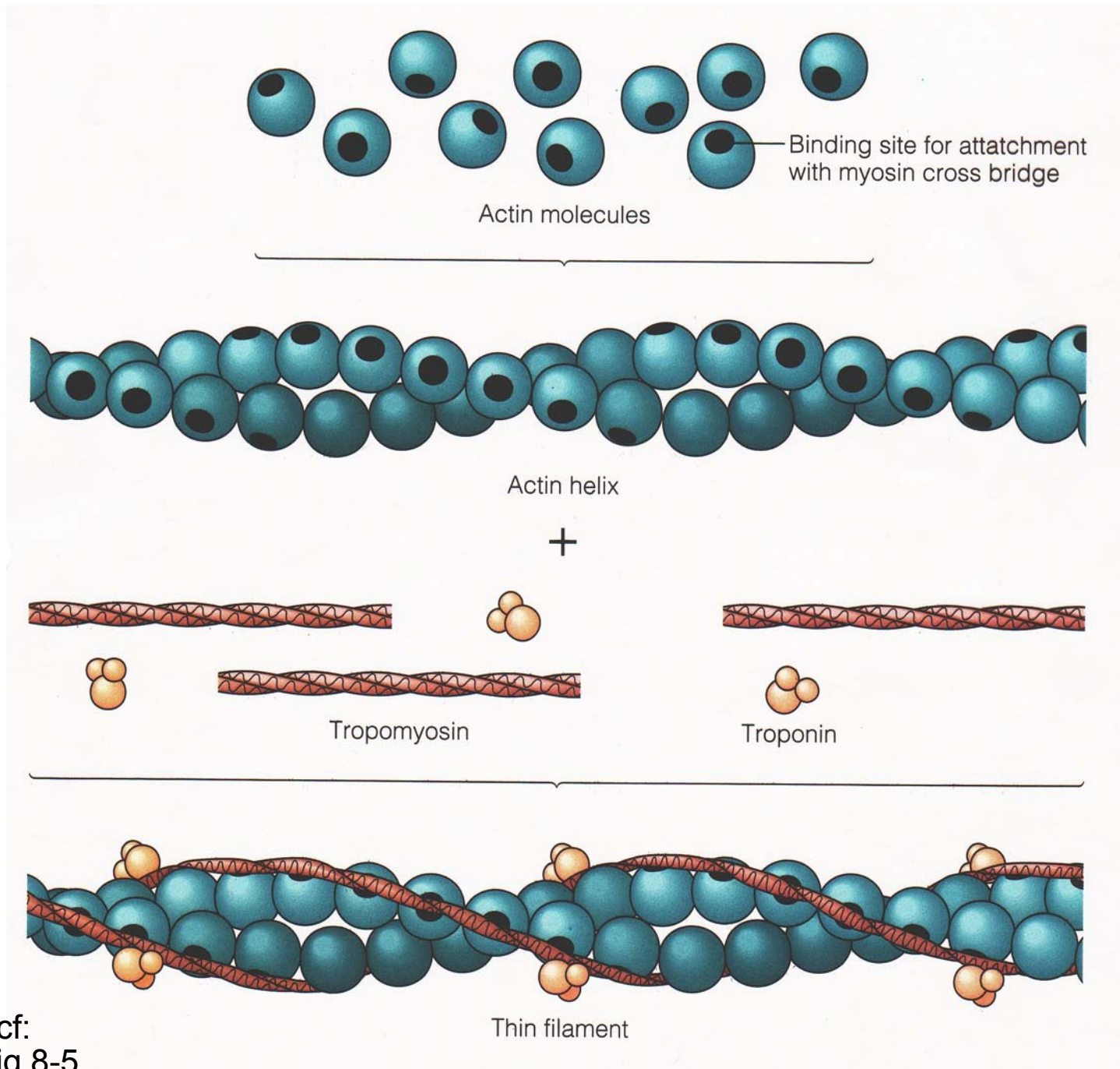
## ***Golf Club Analogy?***



(b)

# *Broccoli Analogy?*





LS 2006, cf:  
LS 2012 fig 8-5



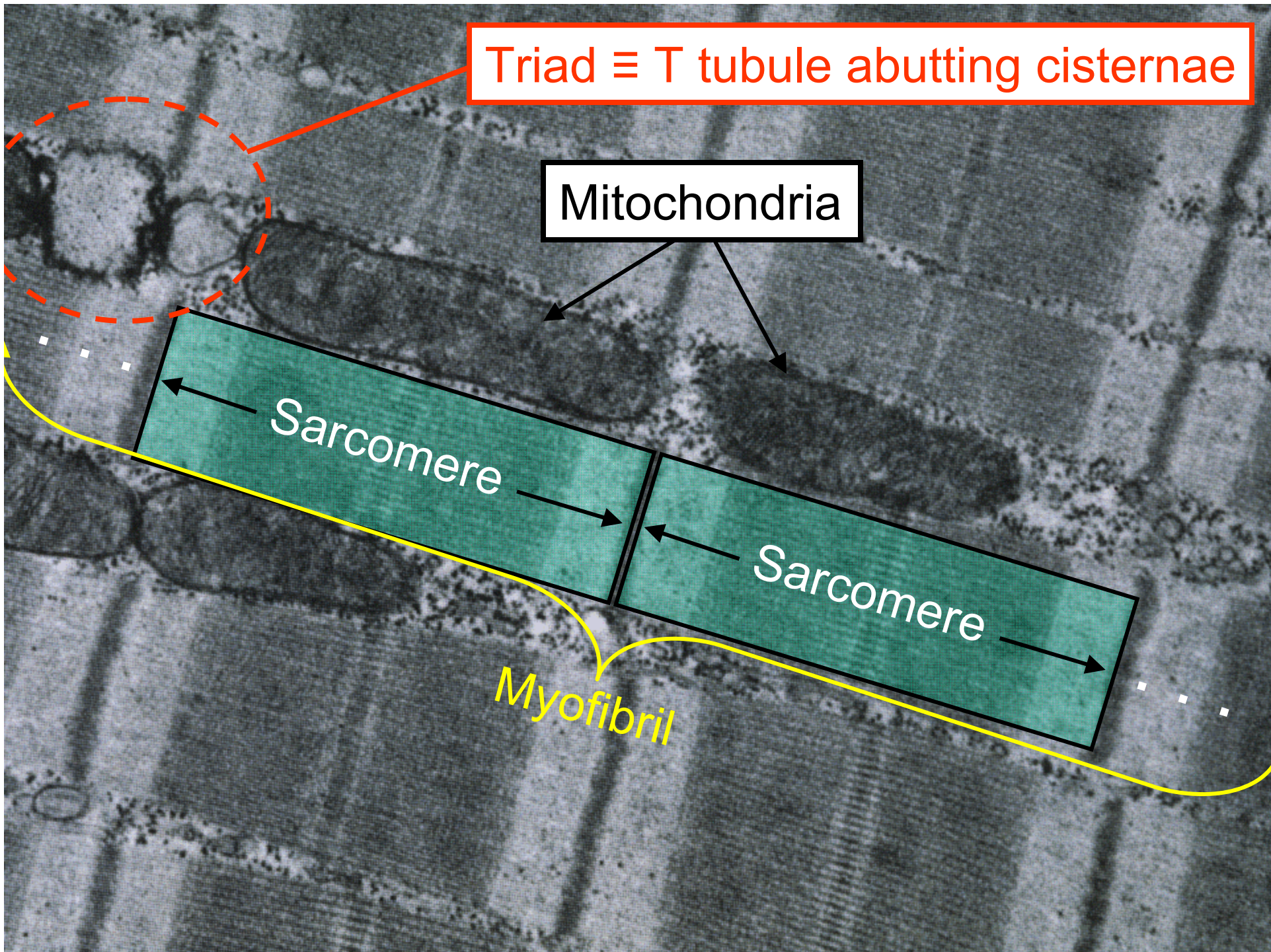
Triad  $\equiv$  T tubule abutting cisternae

Mitochondria

Sarcomere

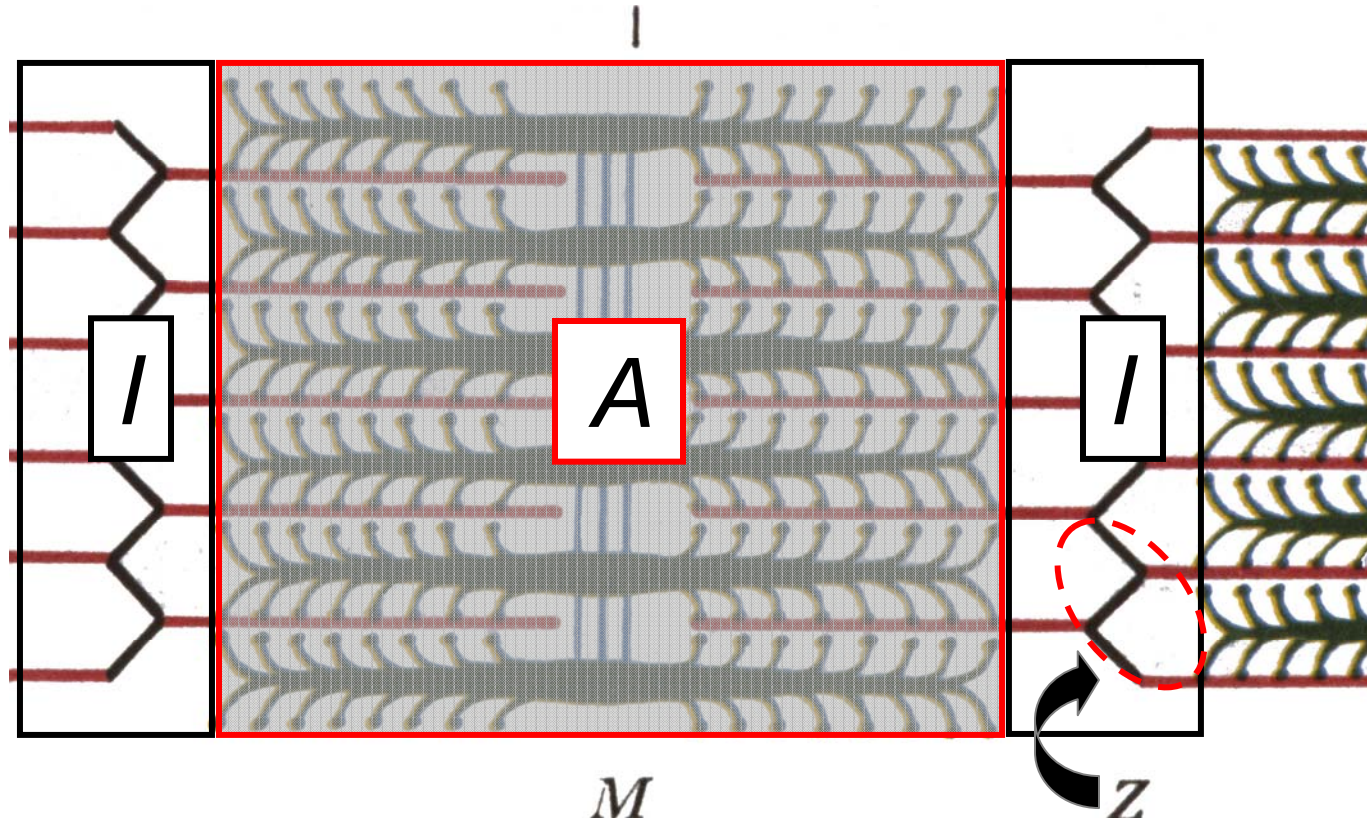
Sarcomere

Myofibril

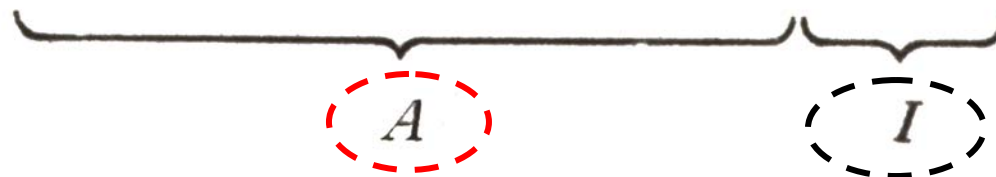




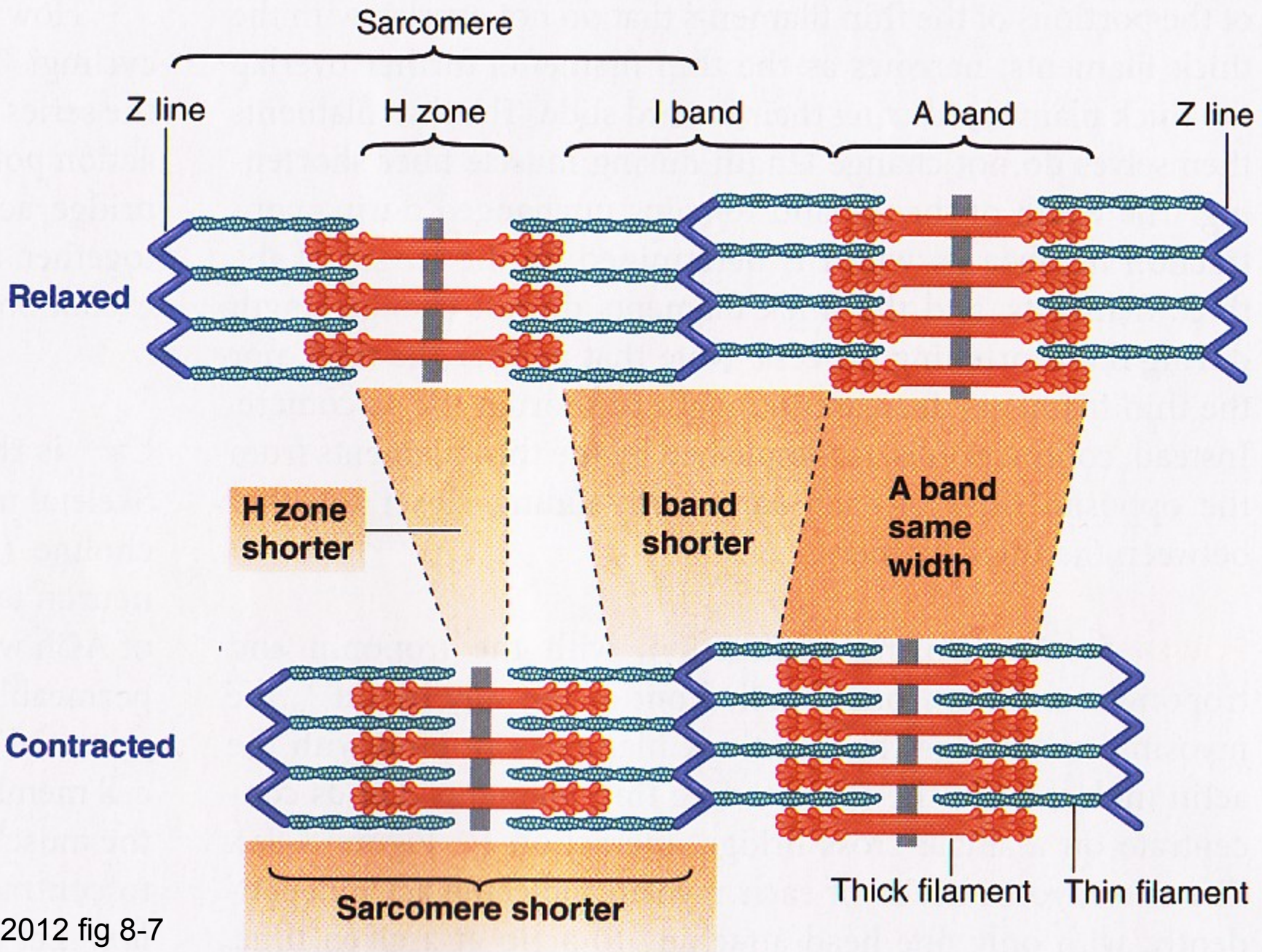
A Band = Dark Band  
Anisotropic = Light Can't Shine Through



I Band = Light Band  
Isotropic = Light Can Shine Through







LS 2012 fig 8-7



# Discussion

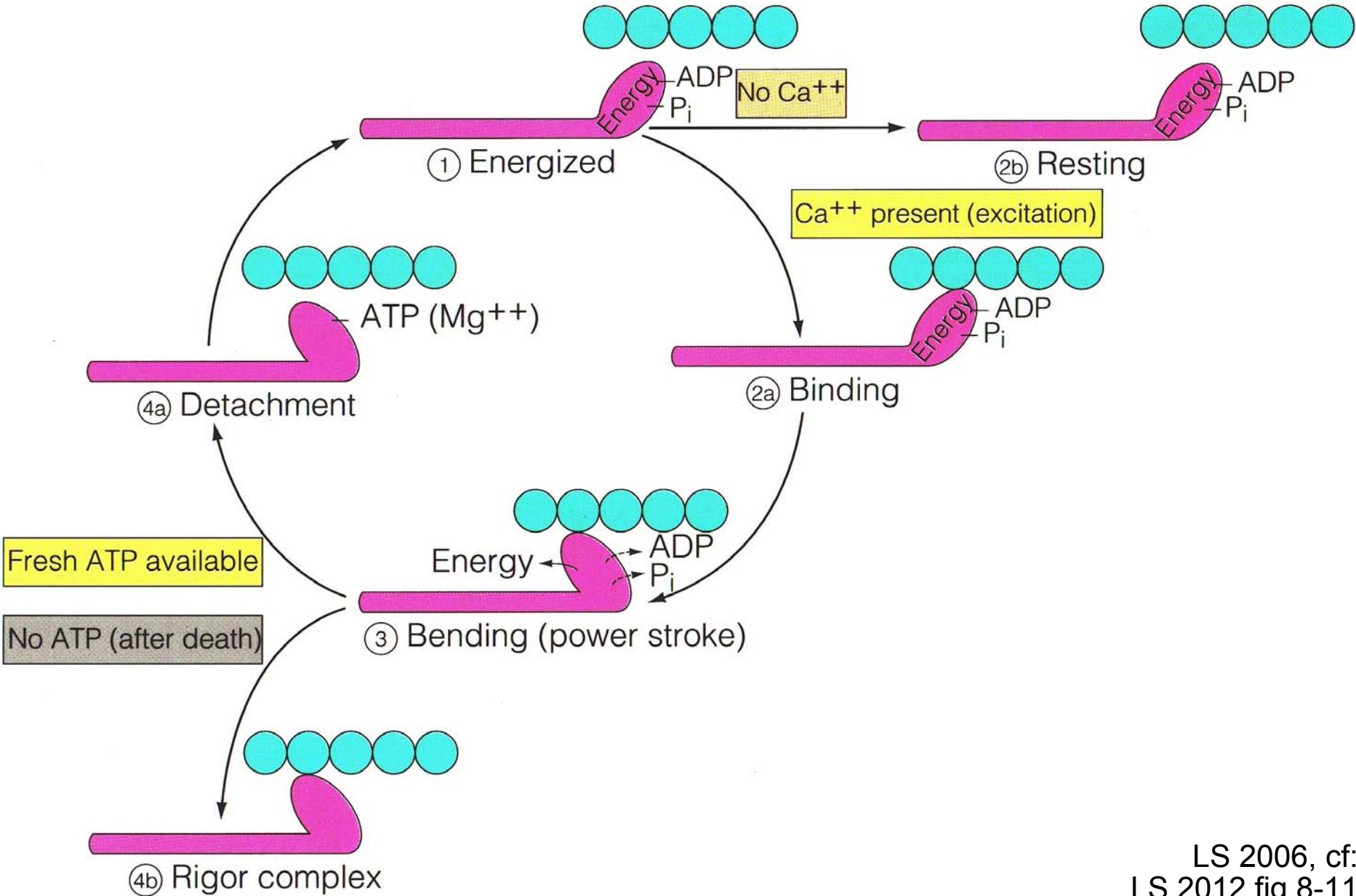
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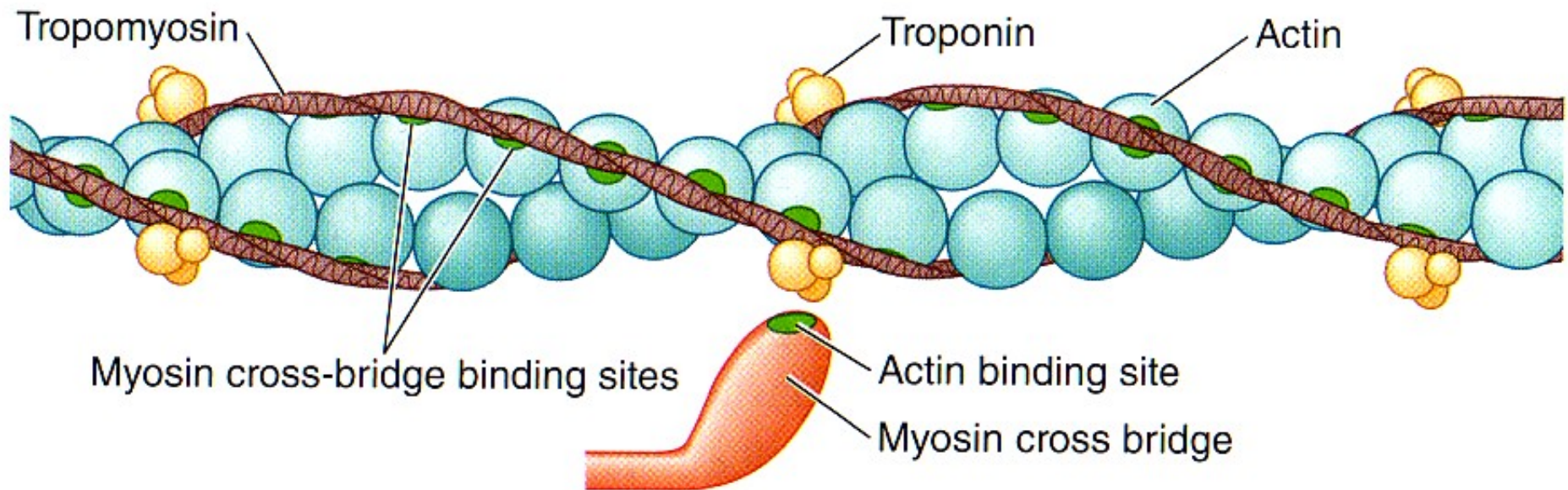
for Q?

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

# Cross-Bridge Cycle



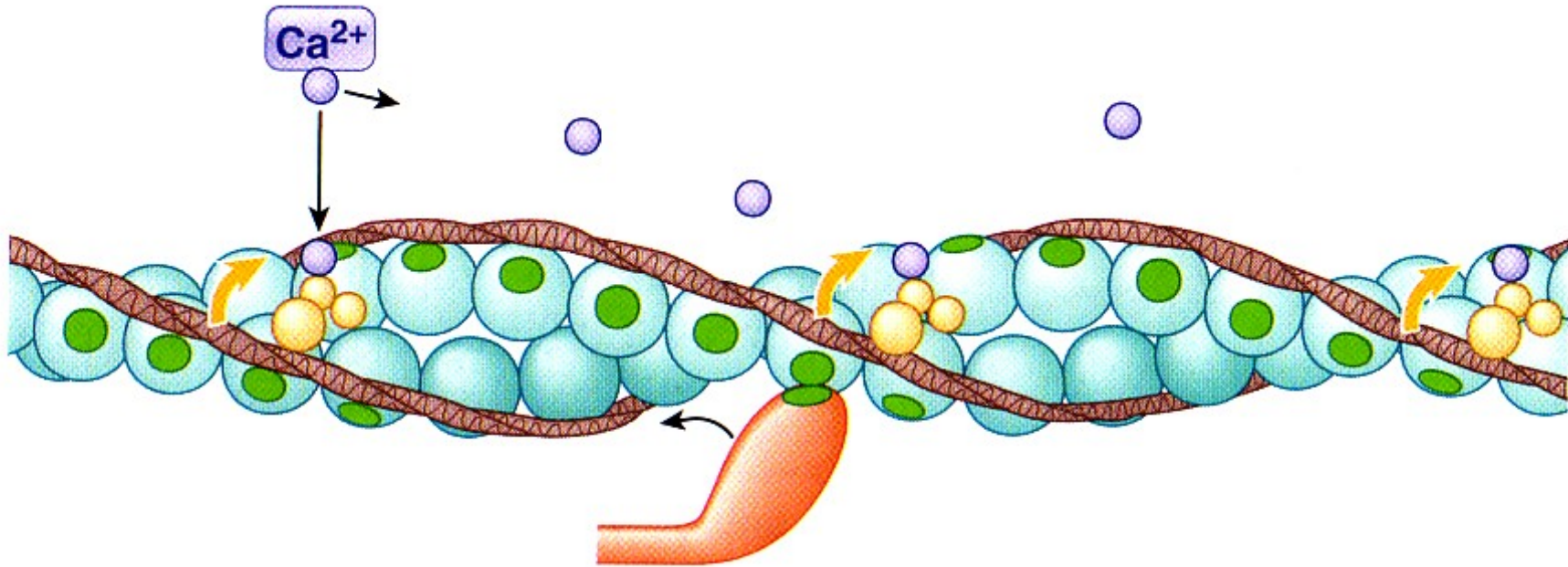
## *Relaxed: No Cross-Bridge Binding*



### **(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***

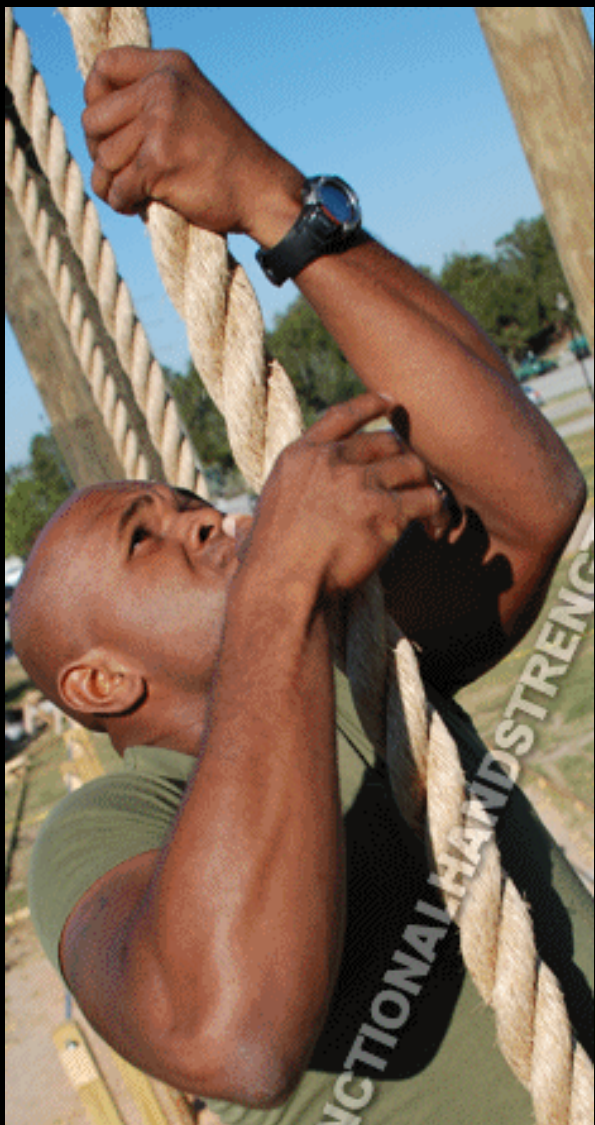


### **(b) Excited**

- 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.

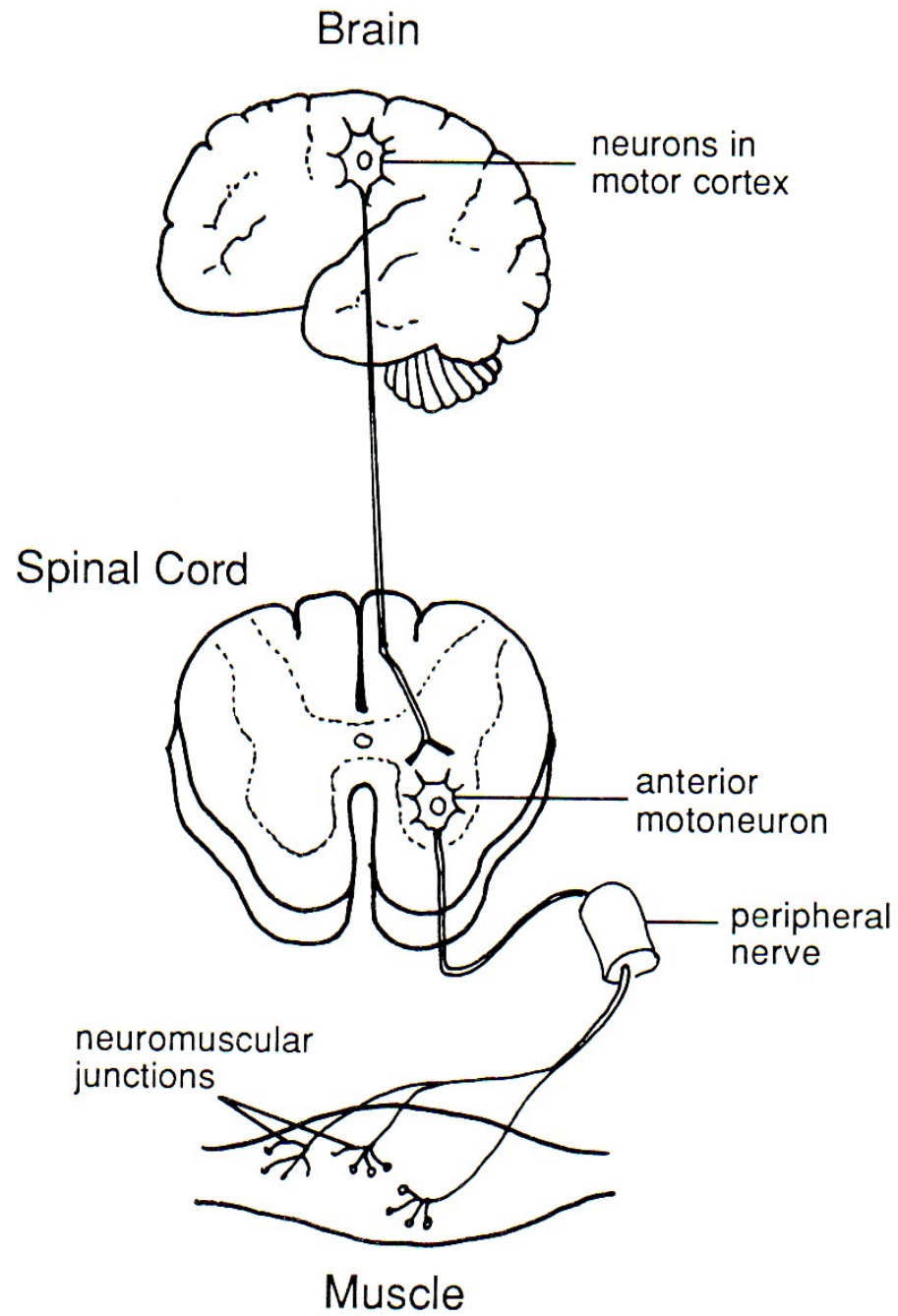


# *Rope Climb or Tug of War Grasp, then Regrasp!*

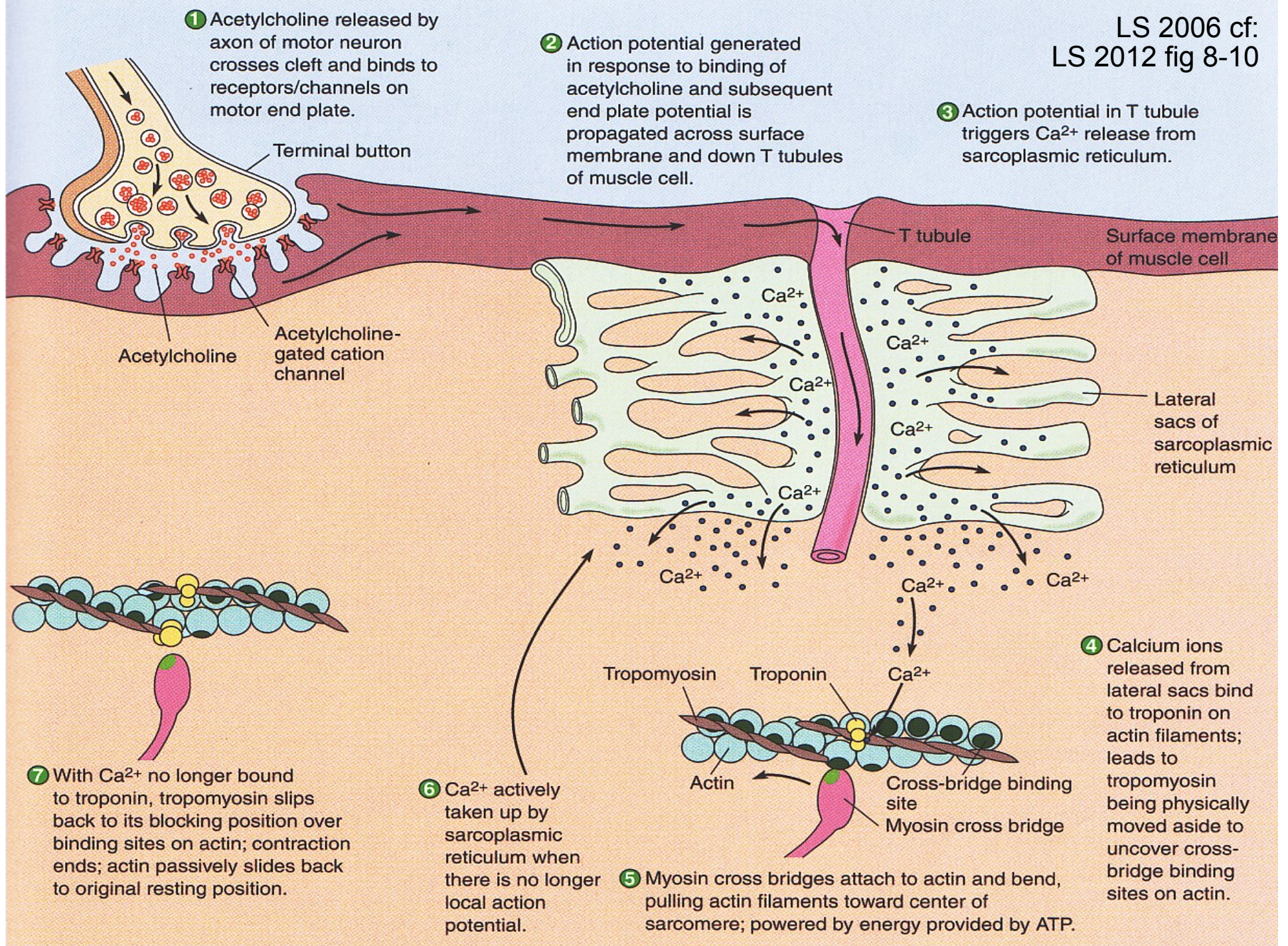




# ***Summary***

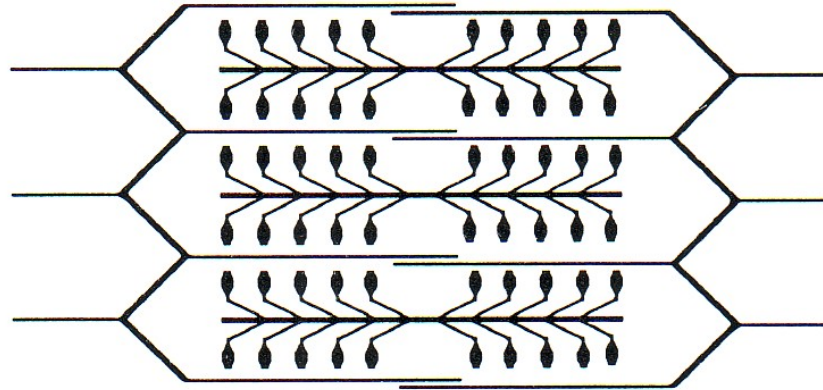






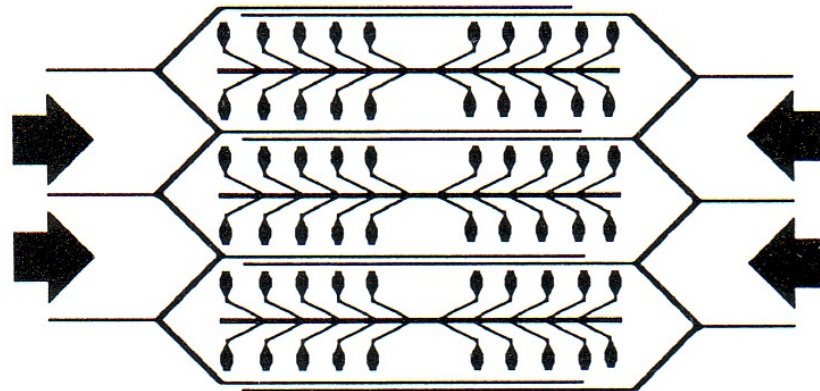


## Relaxation Phase



1. Excitation by nerve fiber
2. Conduction by T-tubules
3.  $\text{Ca}^{2+}$  release by SR

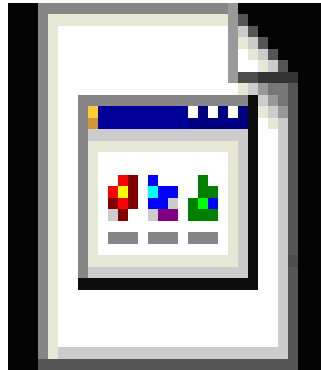
## Contractile Phase



D Liang & VP  
Lombardi 1989

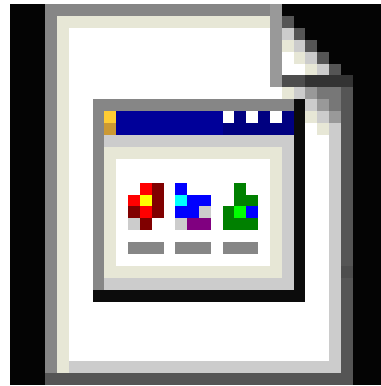


***David Bolinsky, XVIVO***  
***Rocky Hill, CT***  
***<http://www.xvivo.net/>***



muscleanimation.mov

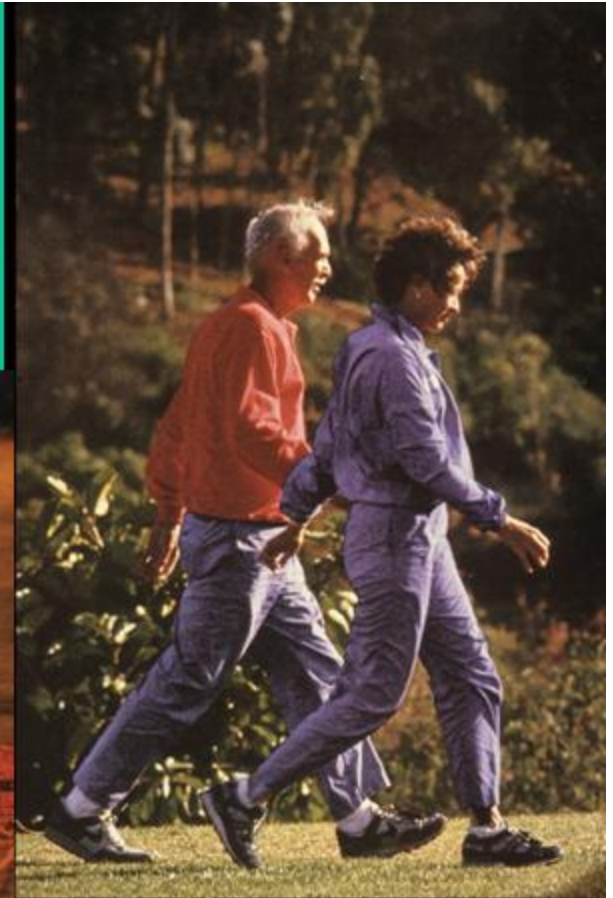
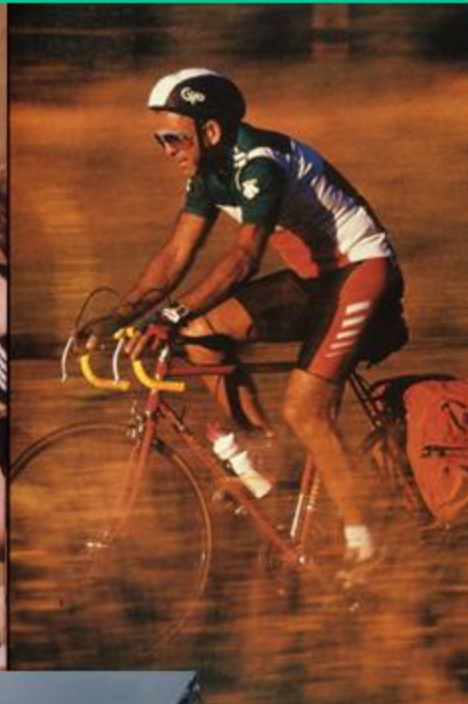
***A. Malcolm Campbell***  
***Davidson College, Davidson, NC***  
***[http://www.bio.davidson.edu/misc/  
movies/musclcp.mov](http://www.bio.davidson.edu/misc/movies/musclcp.mov)***



**Musclcp.mov**

# Adaptations to Exercise?

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

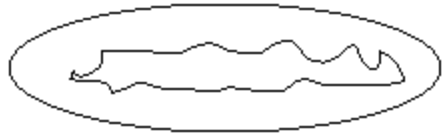
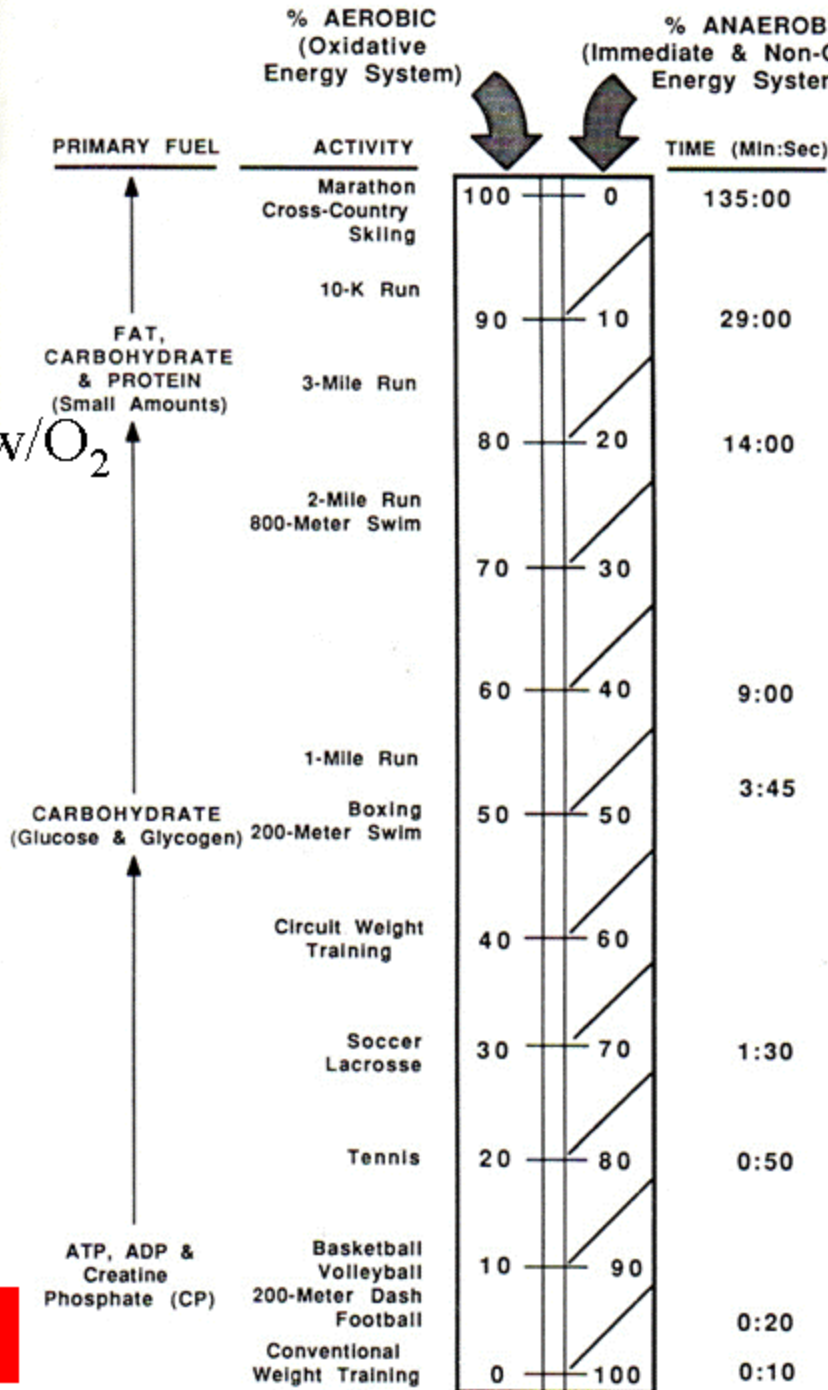






**AEROBIC**

w/O<sub>2</sub>



**MITOCHONDRIA**

**CYTOSOL**

Glycolysis

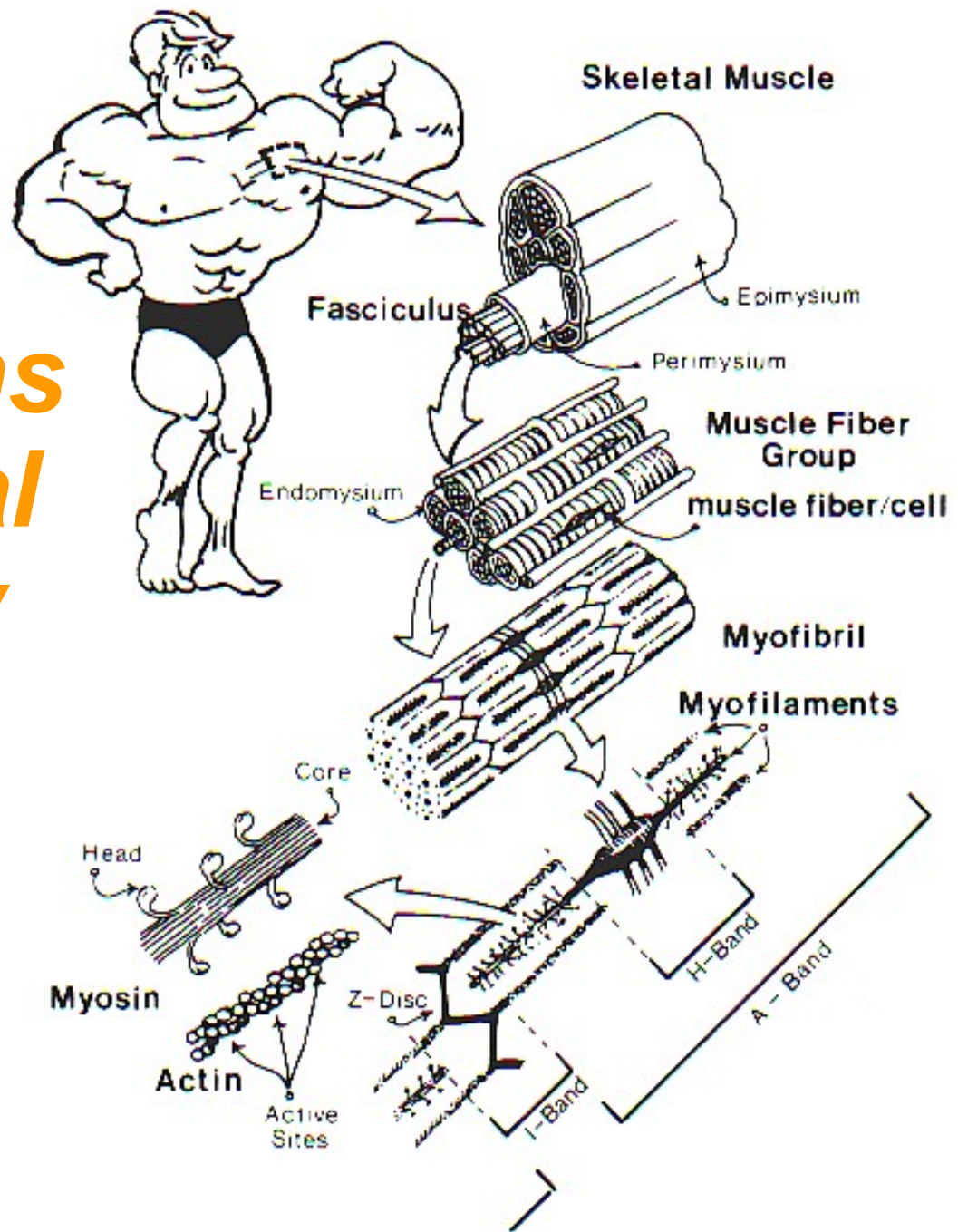


Immediate/ATP-PC



**ANAEROBIC**

# *Adaptations to Skeletal Voluntary Muscle*





## Atrophy

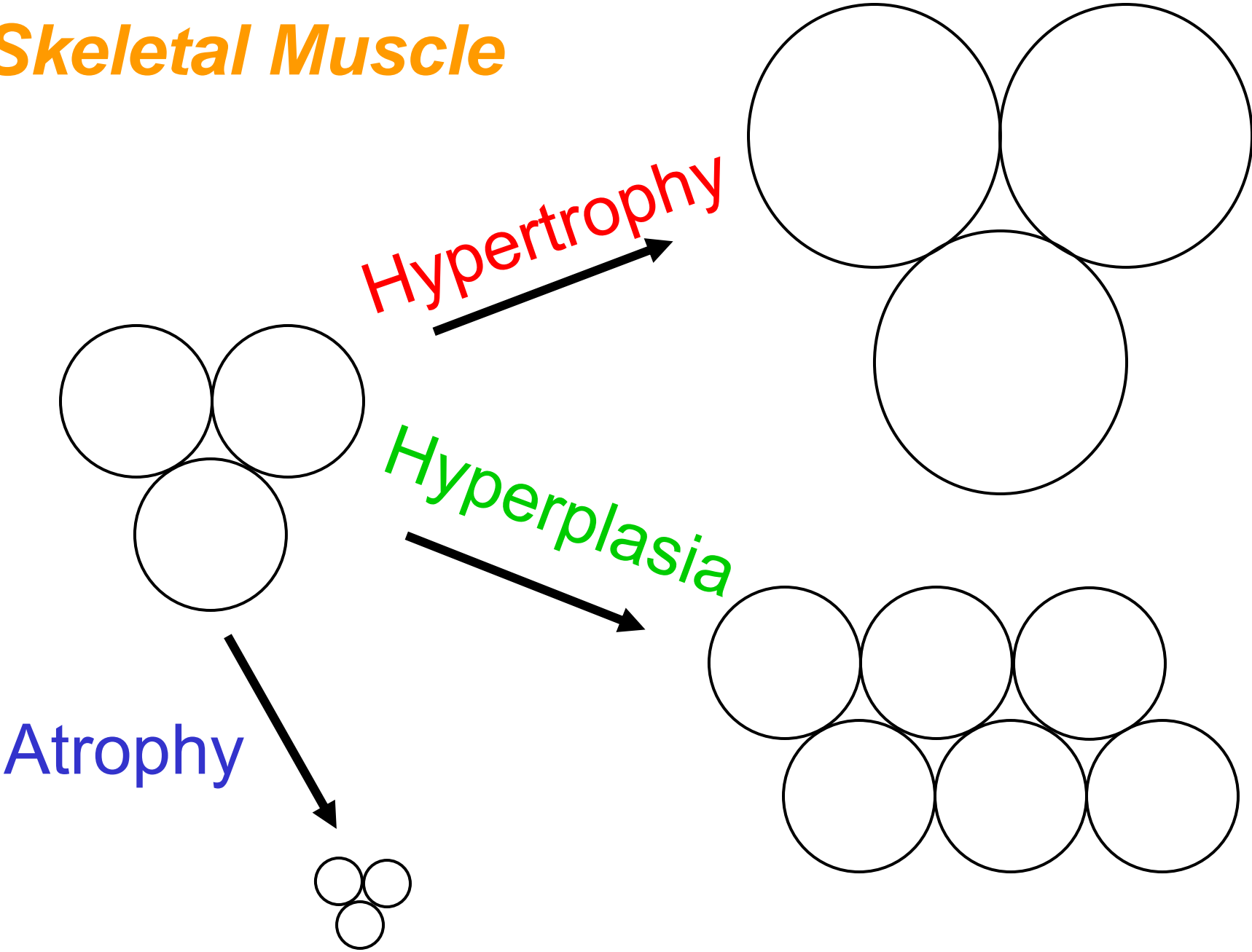
*decrease in size  
& strength*

## Hypertrophy

*increase in size  
& strength*



# *Skeletal Muscle*



# ***Women & Hypertrophy?***



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





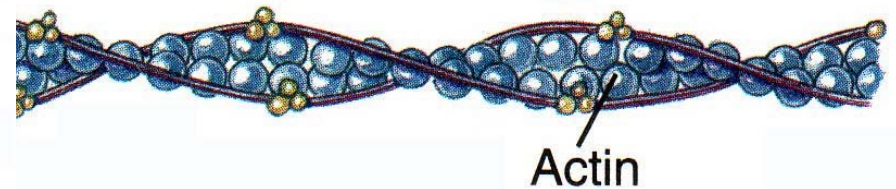
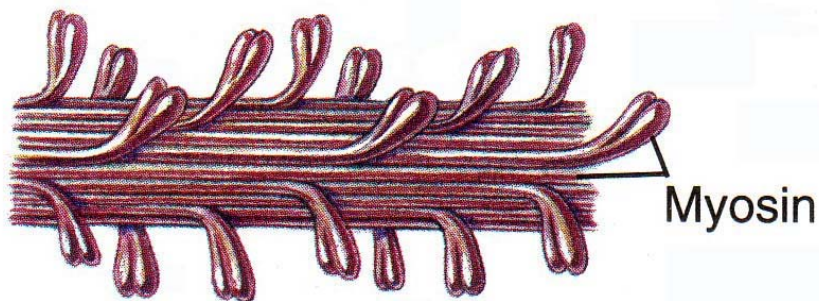
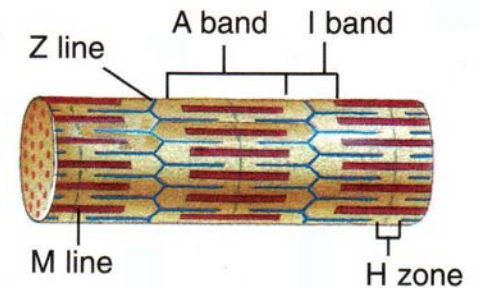


***Hypertrophy: Increased***

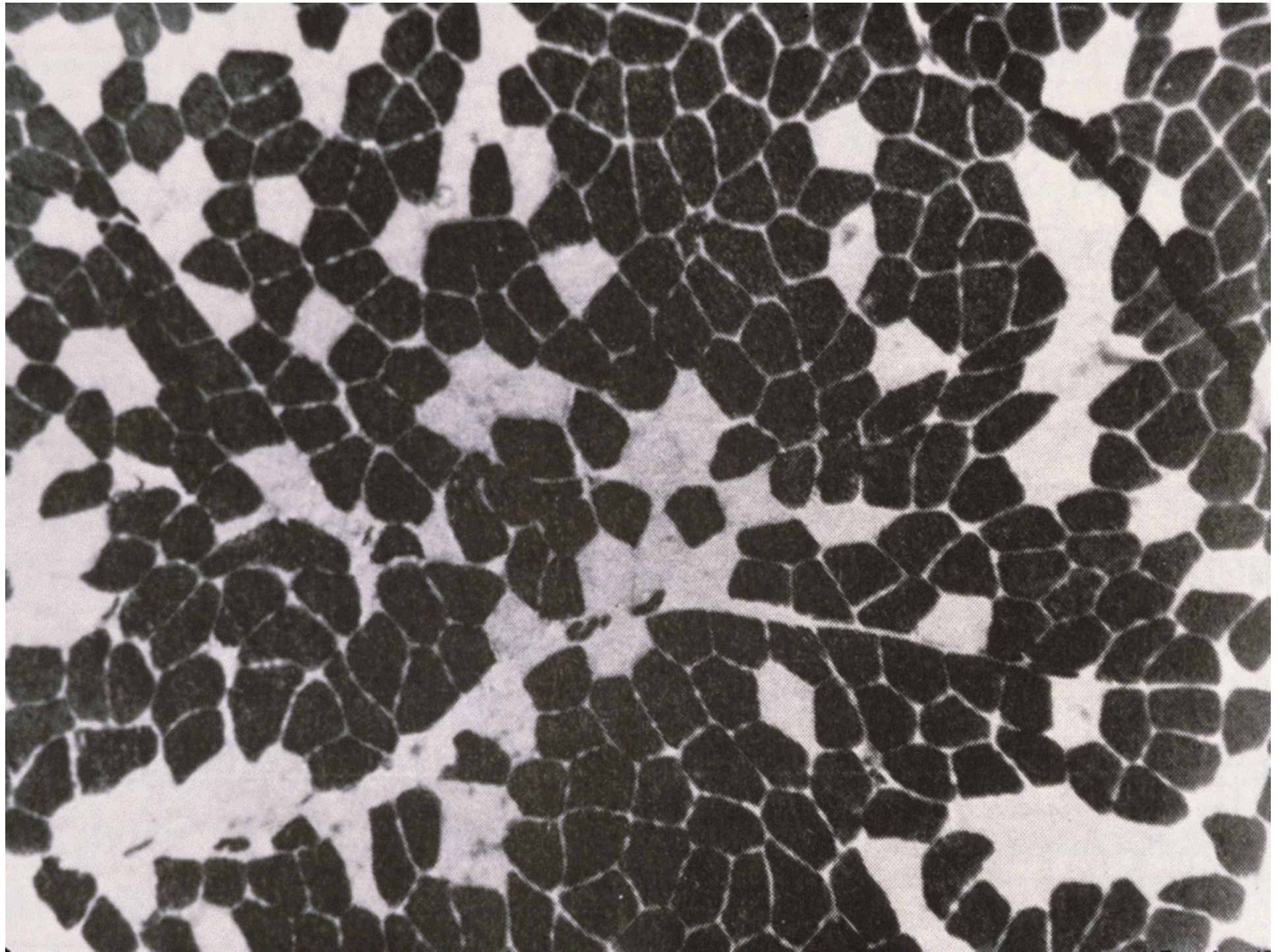
***Number of Myofibrils***

***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



# ***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  $O_2$  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:





?









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