BI 121 Lecture 13

I. **Announcements**

No lab today – Study for Exam II!!

Optional Lab notebook check after last Lab 6, Mac pulmonary function testing (PFT) next Thursday. Q?

II. **Peripheral Nervous System Connections**

LS sections of ch 3, 4, & 7

A. How do excitable cells signal? ch 3 pp 62-7; ch 4 pp 74-83

B. How does the signal cross the nerve-muscle gap?

1. Ca\(^{2+}\) bones!…but what else? p 190
2. What do black widow spider venom, botulism, curare & nerve gas have in common? Botox pp 189-92

III. **Muscle Structure + Function**

LS ch 8 + DC Module 12

A. Muscle types: cardiac, smooth, skeletal LS fig 8-1 pp 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. Thin filaments? Banding pattern LS fig 8-5, 8-3, 8-7

E. How do muscles contract? LS fig 8-6, 8-10

F. What's a cross-bridge cycle? LS fig 8-11 +…
Why are nerve & muscle unique?

They are excitable!!
Action Potentials ≡ Spikes ≡ Impulses

Ultra-short reversal of membrane potential
Only in nerve and muscle cells
Maintains strength over distance

Primary way nerves & muscles communicate!
"Resting"/Membrane Potential?

Cells are slightly negative inside!
Stimulate Cell @ Rest

- Thermal
- Mechanical
- Electrical
- Chemical
Changes Cell Membrane Permeability to Sodium/Na+!

+ Charges/Na+ Rushes In!
Action Potential has occurred!

Brief (1-2 ms) reversal to + inside cell!
Triggering event

Depolarization (decreased membrane potential)

Influx of Na\(^+\) (which further decreases membrane potential)

Opening of some voltage-gated Na\(^+\) channels

Positive-feedback cycle!
= Action potential

= After hyperpolarization

Na⁺ equilibrium

Threshold

Resting potential

K⁺ equilibrium

stimulus

1 msec

Time (msec)
Synapse =
Generic term =
connection between excitable cells!
Neuromuscular junction = Nerve-muscle connection

H Howard 1980
Myelin

Acetylcholine Vesicles

Node of Ranvier

Myelin
Synapse Animation

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

LS 2012 fig 4-14

NT Balance!

Uptake

Release
Other Links That May Be Helpful!

https://www.youtube.com/watch?v=6RbPIOq0O3w
https://www.youtube.com/watch?v=mItV4rC57kM
https://www.youtube.com/watch?v=WhowH0kb7n0
http://sites.sinauer.com/psychopharm2e/animation03.01.html
https://www.youtube.com/watch?v=VitFvNvRI1Y
Time for a break! 😊
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 make up body systems

Cells

LS 2012 ch 8 vignette
Striated muscle

Skeletal muscle

Cardiac muscle

Unstriated muscle

Smooth muscle

Voluntary muscle

Involuntary muscle

LS 2012 fig 8-1
Muscle fiber or cylindrical cell

“Threads” ≡ Myofibrils

Nuclei

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
DC 2013 fig 12-3
Golf Club Analogy?

(a)

(b)

Actin binding site
Myosin ATPase site
Heads

Tail

100 nm

Cross bridges

Myosin molecules

LS 2006, cf:
LS 2012 fig 8-4
Broccoli Analogy?

Myosin Heads

Myosin Tails

Bare Zone

Myosin Heads
Actin molecules

Actin helix

Tropomyosin

Troponin

Thin filament

Binding site for attachment with myosin cross bridge

LS 2006, cf:
LS 2012 fig 8-5
Triad ≡ T tubule abutting cisternae

Mitochondria

Sarcomere

Myofibril
A Band = Dark Band
Anisotropic = Light Can’t Shine Through

I Band = Light Band
Isotropic = Light Can Shine Through
Discussion + Time for Questions!
What do we guess happens at the molecular level?
Cross-Bridge Cycle

1. Energized
   - ATP (Mg++)
   - Energy
   - ADP
   - P_i
   - No Ca++

2a. Binding
   - Ca++ present (excitation)
   - Energy
   - ADP
   - P_i

2b. Resting
   - Energy
   - ADP
   - P_i

3. Bending (power stroke)
   - Energy
   - ADP
   - P_i

4a. Detachment
   - Fresh ATP available

4b. Rigor complex
   - No ATP (after death)
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.

LS 2012 fig 8-6a
(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
We are almost there!
Brain

- neurons in motor cortex

Spinal Cord

- anterior motoneuron

Muscle

- neuromuscular junctions

- peripheral nerve
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 Ca\(^{2+}\) release from sarcoplasmic reticulum.

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.

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

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

7. With 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.
Relaxation Phase

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

Contractile Phase

D Liang & VP
Lombardi 1989