 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? Ca2+ 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...
Homeostasis is a dynamic balance between the autonomic branches.

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

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

D Silverthorn 2010
PARASYMPATHETIC = RESTING, DIGESTIVE, HOUSEKEEPING FUNCTIONS
FIGHT/FLIGHT/ALARM REACTION!!
Why overlap or dual innervation?

Fine-tune control & safety!

cf: LS 2012 fig 7-3
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!

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

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

LS 2012 fig 4-14
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.

Homeostasis is essential for survival of cells

Cells make up body systems

Cells
Skeletal Muscle Histology: Microscopic Anatomy

Muscle fiber or cylindrical cell

“Threads” ≡ Myofibrils

Nucleii

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

x1000

H Howard 1980.
Organ = Muscle → Cell = Myocyte = Fiber

Subcellular = Cytoskeleton

Molecules = Actin & Myosin

Golf Club Analogy?

(a) Actin binding site
Myosin ATPase site

(b) Cross bridges
Myosin molecules

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

Myosin Heads

Myosin Tails

Bare Zone

Myosin Heads
Triad $\equiv$ 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

+

for Q?
What do we guess happens at the molecular level?
Cross-Bridge Cycle

1. Energized

2a. Binding
   - Energy
   - ADP
   - Pi

2b. Resting
   - No Ca++
   - Energy
   - ADP
   - Pi

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

4a. Detachment
   - Fresh ATP available

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

LS 2006, cf: LS 2012 fig 8-11
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 Ca\(^{2+}\) is released.

2. Released 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 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
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
Adaptations to Exercise?
Mode, Intensity, Duration, Frequency, Distribution of Training Sessions?
Conditions of Environment? Individual?
Adaptations to Skeletal Voluntary Muscle
Atrophy

*decrease in size & strength*

Hypertrophy

*increase in size & strength*
Skeletal Muscle

- Hyperplasia
- Hypertrophy
- Atrophy
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

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Slow Oxidative (Type I)</th>
<th>Fast Oxidative (Type IIa)</th>
<th>Fast Glycolytic (Type IIb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myosin-ATPase Activity</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Speed of Contraction</td>
<td>Slow</td>
<td>Fast</td>
<td>Fast</td>
</tr>
<tr>
<td>Resistance to Fatigue</td>
<td>High</td>
<td>Intermediate</td>
<td>Low</td>
</tr>
<tr>
<td>Aerobic Capacity</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Anaerobic Capacity</td>
<td>Low</td>
<td>Intermediate</td>
<td>High</td>
</tr>
<tr>
<td>Mitochondria</td>
<td>Many</td>
<td>Many</td>
<td>Few</td>
</tr>
<tr>
<td>Capillaries</td>
<td>Many</td>
<td>Many</td>
<td>Few</td>
</tr>
<tr>
<td>Myoglobin Content</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Color of Fibers</td>
<td>Red</td>
<td>Red</td>
<td>White</td>
</tr>
<tr>
<td>Glycogen Content</td>
<td>Low</td>
<td>Intermediate</td>
<td>High</td>
</tr>
</tbody>
</table>

LS 2012 tab 8-1 modified  > VP Lombardi 1989
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 (β-oxidation) of fatty acids
↑ Myoglobin (enhances O₂ 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?