I. **Announcements** Civil War Blood Drive! Lab 6, Pulmonary Function Testing (PFT) + optional notebook check today. Exam II Dec 7 Thursday, 8 am!

II. **Skeletal Muscle Structure & Function Connections** Banding pattern, crossbridge cycling, crucial calcium! Contraction & relaxation LS ch 8, DC Module 12

III. **Skeletal Muscle & Other Exercise Adaptations** Endurance vs. Strength training, the Energy Continuum LS ch 8 +…

IV. **Introduction to PFT Lab 6** Pulmonary Function Testing Lab Manual, pp 6-1 thru 6-8

V. **Respiratory System** LS ch 12, DC Module 7, Fox +…
   A. Steps of respiration? External vs. cellular/internal? LS fig 12-1 pp 345-347
   B. Respiratory anatomy LS fig 12-2 p 347, DC, Fox +…
   C. Histology LS fig 12- 4 pp 347-349, DC
Rivals for Life!

Last year’s totals:

OSU  2629
UO   2153

Donate @ Lillis today!

Score of the game?

Donate @ Lillis today!

http://www.redcrossblood.org/info/pnw/civil-war-blood-drive-scoreboard
A Band = Dark Band
Anisotropic = Light Can’t Shine Through

I Band = Light Band
Isotropic = Light Can Shine Through
What do we guess happens at the molecular level?
Cross-Bridge Cycle

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

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

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)
(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 the 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.

LS 2012 fig 8-6b
Rope Climb or Tug of War
Grasp, then Regrasp!
Summary
We are almost there!
Acetylcholine released by axon of motor neuron crosses cleft and binds to receptors/channels on motor end plate.

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.

Action potential in T tubule triggers Ca\(^{2+}\) release from sarcoplasmic reticulum.

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.

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

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

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.
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
Muscle Contraction Resources

https://www.ncbi.nlm.nih.gov/books/NBK9961/

https://www.youtube.com/watch?v=jUBBW2Yb5KI

https://www.youtube.com/watch?v=sJZm2YsBwMY

A. Malcolm Campbell
Davidson College, Davidson, NC
www.bio.davidson.edu/courses/movies.html

David Bolinsky, XVIVO
Rocky Hill, CT
http://www.xvivo.net/
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?
Echocardiography documents hypertrophy...
Cardiac Adaptations to Exercise:

1. Endurance vs.
2. Strength Training

NB: ① > ↑ LBM
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

Atrophy → Hyperplasia

Hypertrophy → Hyperplasia
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>
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?
Dancing can be super aerobic exercise, too, & you don’t have to be a star!
Extremes of the energy continuum!
Discussion + Time for Questions!
Hey baby, what's your sign?

Cancer.
Lab 6 Review: Pulmonary Function Testing (PFT)

Me, too!

I am healthy, thanks to clean air!

O₂

CO₂

...Life ≡ Balance!

Me, too!

Exercise! Exercise!!

Me, too!

I am healthy, thanks to clean air!
**NB:** Should be able to blow out ≥ 75 - 85% of VC/FVC in 1 second! That's FEV\(_{1.0}\)/FVC ≥ 0.75 – 0.85. If less, may indicate asthma or other lung disease.

*Respirometer → measures complete Pulmonary Function Test or PFT!*
PFT measures all lung volumes & capacities (sum of ≥2 volumes). Subject relaxes & breathes normally into and out of tank.
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!
Lombo’s simplified steps!

1. **Breathe in & out!**

2. **Cross membranes!**

3. **Move with blood!**
   - Go with the flow!

4. **Cross membranes!**

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**STEPS OF EXTERNAL RESPIRATION**

1. **Ventilation or gas exchange between the atmosphere and air sacs (alveoli) in the lungs**

2. **Exchange of O\(_2\) and CO\(_2\) between air in the alveoli and the blood in the pulmonary capillaries**

3. **Transport of O\(_2\) and CO\(_2\) by the blood between the lungs and the tissues**

4. **Exchange of O\(_2\) and CO\(_2\) between the blood in the systemic capillaries and the tissue cells**

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*LS 2012 fig 12-1 modified*
**NB: In vivo,** Cupola or peak of each lung goes into neck > clavicle line!
16-20 C-shaped bars of hyaline cartilage to prevent collapse
Vocal cords which approximate (move closer together) during Valsalva’s maneuver!
Pulmonary Latex Cast with Colored Segmentation
Bronchograms: bronchial tree x-rays > injecting contrast

Source: Gardner, Gray, O’Rahilly, Anatomy, fig 29-11, p 295.
No Gas Exchange

1st alveolar outpouching!

Gas Exchange
The last cilium on a smoker’s lung

Shoot... If only I had a red five.
Capillaries with rbcs!

← Alveoli →

White Blood Cell