Physiology of the Musculoskeletal System

Chapters 7 & 8
1. Neuromuscular Anatomy
Neuromotor System

Central Nervous System

Peripheral Nervous System
Neuron

- Axon
- Myelin sheath
- Nodes of Ranvier
- Schwann cell
- Layers of myelin
- Nucleus of Schwann cell
- Axon
- Node of Ranvier
Action Potential
Afferent & Efferent

Afferent

Sensory (afferent) Neurons

Sensory receptor

Effector

Efferent

Motor (afferent) Neurons

Peripheral nervous system (PNS)

Central nervous system

Motor output

Integration

Interneurons

Brain and spinal cord
Motor Neurons

Fast

Motor neuron A

Slow

Motor neuron B
Neuromuscular Junction

- Neuron
- Synaptic knob
- Cleft
- Muscle cell
- Axon of nerve cell
- Muscle fiber

[Diagram of neuromuscular junction showing the interaction between a neuron and muscle cell.]
Note: This motor unit has a 3:1 ratio. Actual motor units range from 20:1 to 2,000:1.
2. Muscle Anatomy Overview
Muscle Fiber Anatomy

Note: muscle fiber = muscle cell
Muscle Fiber Anatomy

- Sarcolemma
- Mitochondrion
- Myofilaments
- Myofibrils
- Z disc
- A band
- I band
- Sarcomere
- Thick filament
- Thin filament
- Troponin complex
- Actin
- Tropomyosin
- Myosin

Muscle fiber
Nuclei
T tubules
Sarcoplasmic reticulum
The sarcomere: The basic functional unit of a myofibril.
1. Troponin
2. Tropomyosin
3. Actin
Actin & Myosin

Diagram showing the interaction between Actin and Myosin, highlighting different components such as Troponin T (~15%), α-Tropomyosin (<5%), Troponin C, Troponin I, Myosin-binding protein C (~15%), Myosin light chain (<1%), β-Myosin heavy chain (~35%), and Myosin rod.
3. The Sliding Filament Theory

Excitation-Contraction Coupling
Step-by-Step Summary of Excitation-Contraction Coupling p. 145

Web site on sliding filament theory

http://www.blackwellpublishing.com/matthews/myosin.html

http://muscle.biomol.uci.edu/mus1011.htm

http://muscle.ucsd.edu/more_html/overview.shtml
Neural Stimulation
Depolarization

ACh = acetylcholine
Cross-Bridges & Power Strokes
Sliding
Sliding

Relaxed

Partial

Maximal
ATP and Muscle Contraction

I. Troponin/tropomyosin complex blocks access to the cross bridge binding sites on the actin molecules.

II. When calcium is released into the fiber, it binds with troponin which pulls the troponin/tropomyosin complex away from the binding sites.

+ Calcium (Ca++)

III. Binding of the myosin cross bridge with actin takes place.

IV. Binding triggers a hinge-like movement of the cross bridge inward. The thin filament is pulled toward the center of the sarcomere.
1. **Resting**

   - **Sarcolemma**

2. Action potential in the sarcolemma carried to the interior of the cell through the T tubules.

3. Action potential triggers release of Ca^{2+} from the sarcoplasmic reticulum (SR).

4. Calcium binds to Tn-C subunit of troponin, causing exposure of the actin active site.

5. Activated myosin head binds to active site pulling the actin over the myosin and contracting the sarcomere.

6. Ca^{2+} removed by uptake into the SR; contraction ends; tropomyosin restored to blocking position.
Quick Time Movie

This Quick Time Movie of the contraction process can be downloaded at the class web page.
4. Types of Muscle Contraction

- Static contraction
  - Isometric
- Dynamic contraction
  - Concentric
  - Eccentric
Isometric or Static Contraction
Isometric contraction
Muscle contracts but does not shorten

No movement
Concentric Contraction
Concentric contraction

Movement
Eccentric Contraction
Eccentric contraction
Eccentric Contraction
Eccentric Contraction

(b) Movement of the forearm

Copyright © 2001 Benjamin Cummings, an imprint of Addison Wesley Longman, Inc.
5. Muscle Fiber Types

<table>
<thead>
<tr>
<th>Muscle Fibers</th>
<th>Twitch properties</th>
<th>Metabolic properties</th>
<th>Name based on twitch and metabolic properties</th>
<th>Other nomenclature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Slow</td>
<td>Fast</td>
<td>SO</td>
<td>ST, Type I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FOG</td>
<td>FTa, FTA, Type IIA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FG</td>
<td>FTb, FTB, Type IIB</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Motor Neurons</th>
<th>Neuron type</th>
<th>Neuron size</th>
<th>Conduction velocity</th>
<th>Recruitment threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\alpha_2$</td>
<td>Small</td>
<td>Slow</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>$\alpha_1$</td>
<td>Large</td>
<td>Fast</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>$\alpha_1$</td>
<td>Large</td>
<td>Fast</td>
<td>High</td>
</tr>
</tbody>
</table>

Most Common: Slow twitch/Type I, Fast twitch A/Type IIA, and Fast twitch B/Type IIB
# Fiber Type Characteristics (Table 8.1)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Type IIb</th>
<th>Type Ila</th>
<th>Type I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistance to fatigue</td>
<td>Low</td>
<td>High/mod</td>
<td>High</td>
</tr>
<tr>
<td>Predominant energy system</td>
<td>Anaerobic</td>
<td>Combination</td>
<td>Aerobic</td>
</tr>
<tr>
<td>Speed of shortening</td>
<td>Fastest</td>
<td>Intermediate</td>
<td>Slowest</td>
</tr>
<tr>
<td>Force production</td>
<td>High</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Fiber Diameter</td>
<td>Large</td>
<td>Intermediate</td>
<td>Small</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fiber Typing
Fiber Typing

The things I’ll do for extra credit!
Fiber Typing

Type IIa

Type IIb

Type I

Fig 8.12
Fiber Types and Individual Differences

What are the percentages of fiber types in the average person?
## Fiber Type Distribution

<table>
<thead>
<tr>
<th>Sport</th>
<th>Type I</th>
<th>Type II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance Runner</td>
<td>70-80</td>
<td>20-30</td>
</tr>
<tr>
<td>Track Sprinter</td>
<td>25-30</td>
<td>70-75</td>
</tr>
<tr>
<td>Non-athlete</td>
<td>47-53</td>
<td>47-53</td>
</tr>
</tbody>
</table>

Table 8.2
Fiber Type Distribution

- Average person; equal mix
- No sex difference
- No age difference
Fiber Type Distribution
Alterations in Fiber Types

- Shift
  - “skeletal muscle is highly plastic”
- Complete change
  - rigorous and regular exercise
- Fast twitch to Slow twitch
Alteration of Muscle Fiber Type

10 weeks of training on rat fibers

↑ Type I
↑ Type IIa
↑ Type IIx
↓ Type IIb

% Fiber type

Skeletal muscle fiber types

Pretraining
30 min/day
60 min/day
90 min/day
Terms

- Atrophy
  - Conditions when atrophy might occur?
- Hypertrophy
The nervous system sorts and interprets incoming information before directing a response.

A. Receptors in the skin sense a tap or other stimulus.

B. Sensory neurons transmit the touch message.

C. The message is interpreted. A response is sent to the motor neurons.

D. Motor neurons transmit a response message to the shoulder muscles.

E. The neck muscles are activated, causing the head to turn.
Muscle Spindle

- Stretch reflex
  - stretch or increase length of the muscle...
  - ...muscle contraction
Muscle Spindle

Sensory nerve fiber

Nerve endings

Skeletal muscle fiber

Muscle spindle

Connective tissue sheath

Stretch

Contraction
In the patellar reflex, a sensory neuron (red) with a receptor that detects stretch in the quadriceps muscle sends signals to the spinal cord. The axon of the sensory neuron is split. One branch (green) stimulates motor neurons in the quadriceps, causing the muscle to contract and extend the leg. The other branch (blue) stimulates an interneuron which inhibits motor neurons in the hamstrings.
Golgi Tendon Organ

Fig 8.22