The Muscular System

- Characteristics of Skeletal Muscle Contraction
- Types of Muscle Contraction
- Heat Production
- How Muscles Move the Body
- Muscle Disorders
Introduction

- Myogram
  - Measures muscle response to nervous stimulation
The Muscle Twitch

- Response of a muscle to a single brief threshold stimulus
  - Provoked in a laboratory setting
  - Not observed in normal muscle
The Muscle Twitch

- Three phases of a twitch
  1. Latent period
     - Events of excitation-contraction coupling
  2. Contraction phase
     - Cross bridge formation
     - Tension increases
  3. Relaxation phase
     - Ca$^{2+}$ re-entry into the SR
     - Tension declines to zero
Latent period
Period of contraction
Period of relaxation

(a) Myogram showing the three phases of an isometric twitch
The Muscle Twitch

- **Threshold**
  - Minimum stimulus (voltage) required to cause contraction
- $\uparrow$ stimulus strength $\neq$ increased contractility
  - All or none principle
Recruitment

Figure 9.13a

Spinal cord
Motor neuron cell body
Muscle
Motor neuron axon
Nerve
Axon terminals at neuromuscular junctions
Motor unit 1
Motor unit 2
Muscle fibers
The Muscle Twitch

- **Motor unit recruitment**
  - Assists in creating graded muscle responses
Motor unit 1 recruited (small fibers)

Motor unit 2 recruited (medium fibers)

Motor unit 3 recruited (large fibers)
The Muscle Twitch

- **Increased frequency of stimulation**
  - Increases force of contraction
    - If stimuli are delivered in rapid succession
  - Second twitch will be stronger than the first
    - “rides on the shoulders” of the first stimulus

- **Treppe**
  - Frequency where muscle has fully relaxed
    - Subsequent contractions are more forceful
Due to incomplete calcium recovery
The Muscle Twitch

- Wave summation
  - 2nd contraction occurs *before* muscle has completely relaxed
A single stimulus is delivered. The muscle contracts and relaxes.
The Muscle Twitch

- **Wave summation**
  - Further increase in stimulus frequency $\rightarrow$ unfused (incomplete) tetanus
    - Sustained but quivering contraction
(b) If another stimulus is applied before the muscle relaxes completely, then more tension results. This is temporal (or wave) summation and results in unfused (or incomplete) tetanus.
The Muscle Twitch

- **Complete tetanus**
  - Maximal contraction
  - All evidence of relaxation disappears
  - Rare
  - Causes rapid fatigue

Disease caused by *C. tetani* bacteria is different!
(c) At higher stimulus frequencies, there is no relaxation at all between stimuli. This is fused (complete) tetanus.
The Muscle Twitch

• Refractory period
  ○ Time required for sarcolemma to repolarize
    ▶ New contractions cannot occur
      ○ Skeletal muscle = thousandths of a second
      ○ Cardiac muscle = very long
        • Prevents tetanus
Types of Muscle Contraction

1. Twitch
   - Abnormal or induced in lab

2. Tetanic
   - Normal, sustained contraction
   - Types
     a) Tonic = partially sustained
     b) Isometric = same length
     c) Isotonic = same tension
Types of Muscle Contraction

- **Tonic**
  - Motor units alternate
  - Keeps muscles firm, healthy and ready to respond
  - Variations
    - Flaccidity (hypotonia)
    - Spasticity (hypertonia)
    - Atrophy
    - Hypertrophy
Isometric Contraction

No movement (constant length) with changing tension

Example: Trying to lift a piano alone
Isotonic Contraction

Muscle length changes and moves the load

Example: lifting a book

May be concentric or eccentric
Types of Muscle Contraction

(a) Concentric contraction while picking up a book
(b) Eccentric contraction while lowering a book
(c) Isometric contraction while holding a book steady

Biceps Brachii

Figure 10.16 Tortora - PAP 12/e
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Heat Production

- 70-80% of energy released during contraction lost as heat
  - Heat derived from
    - ATP breakdown
    - Breakdown of glucose and lactic acid
- Shivering
- Brown fat
How Muscles Move the Body

- Lever systems
  - Muscle contraction → pulling on bones
How Muscles Move the Body

Components of a lever system

1. Lever
   - Rigid bar (bone) that moves on a fixed point or fulcrum (joint)

2. Effort
   - Force (supplied by muscle contraction) applied to a lever to move a resistance (load)

3. Load
   - Resistance (bone + tissues + any added weight) moved by the effort
How Muscles Move the Body

- **Levers**
  - Allow movement of heavy loads
  - Alter rate of movement
  - Increase distance over which a load can be moved
  - Classified by position of force, load and fulcrum
Effort (muscle contraction)  
Fulcrum (joint)  
Lever (bone)  
Load (resistance)
(a) First-class lever

Arrangement of the elements is load-fulcrum-effort

**In the body:** A first-class lever system raises your head off your chest. The posterior neck muscles provide the effort, the atlanto-occipital joint is the fulcrum, and the weight to be lifted is the facial skeleton.
In the body: Second-class leverage is exerted when you stand on tip-toe. The effort is exerted by the calf muscles pulling upward on the heel; the joints of the ball of the foot are the fulcrum; and the weight of the body is the load.
Arrangement of the elements is load-effort-fulcrum

In the body: Flexing the forearm by the biceps brachii muscle exemplifies third-class leverage. The effort is exerted on the proximal radius of the forearm, the fulcrum is the elbow joint, and the load is the hand and distal end of the forearm.
How Muscles Move the Body

- **Organization at joints**
  1. **Prime movers**
     - Provide the major force for producing a specific movement
  2. **Antagonists**
     - Oppose or reverse a particular movement
  3. **Synergists**
     - Add force to a movement
     - Reduce undesirable or unnecessary movement
A single muscle may perform all three functions
- Depends on the movement
- Example
  - Biceps brachii
<table>
<thead>
<tr>
<th>Prime mover</th>
<th>Antagonist</th>
<th>Synergist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biceps brachii</td>
<td>Triceps brachii</td>
<td>Brachioradialis</td>
</tr>
<tr>
<td>Flexor digitorum</td>
<td>Extensor digitorum</td>
<td>Biceps brachii</td>
</tr>
<tr>
<td>Triceps</td>
<td>Biceps brachii</td>
<td>Pectoralis, Deltoid</td>
</tr>
</tbody>
</table>
Muscular Disorders

- **Fibrosis**
  - Fibrous scar tissue

- **DOMS**
  - Microtrauma that damages the fibrils and sarcolemma
Muscular Disorders

- **Fibromyositis**
  - Inflammation of connective tissue of muscle
    - Lumbago
    - Fibromyalgia

- **Cramping**
  - Electrolyte imbalances
  - Dehydration
Muscular Disorders

- Duchene muscular dystrophy
  - Hereditary disease
  - Skeletal muscle degeneration
    - Abnormal protein
- Myasthenia gravis
  - Acetylcholine receptors destroyed
Activities

- Review
  - Muscles 18
  - Muscles 21, #1-10