Ch 8 Part 1 Objectives

• 1) List various outcomes of muscular actions.
• 2) Describe how connective tissue is a part of a skeletal muscle.
• 3) Name the major parts of a skeletal muscle fiber, and describe the function of each.
• 4) Discuss nervous stimulation of a skeletal muscle.
• 5) Identify the major events of skeletal muscle fiber contraction.

• 6) Describe the energy sources for muscle fiber contraction.
• 7) Describe how oxygen debt develops and how a muscle may become fatigued.
• 8) Distinguish between a twitch and a sustained contraction.
• 9) Explain how muscular contractions move body parts and help maintain posture.

Introduction

• There are 650 different muscles in the human body.
• Nearly half of our weight comes from muscle tissue.
• Muscles give us form and shape.
• Muscles produce most of our body heat.

Functions of Muscles

• – Produce skeletal movement
• – Maintain posture and body position
• – Support soft tissues
• – Regulate entering and exiting of material
• – Maintain body temperature

Structure of Muscles

• Each muscle is an organ, comprised of skeletal muscle tissue, connective tissues, nervous tissues, and blood.
  • Connective tissue coverings
    • Fascia – dense connective tissue surrounding each muscle.
    • Extends beyond the ends of the muscle and gives rise to tendons that are fused to the bone.
    • Aponeuroses – broad sheets of connective tissue connecting muscles
• Epimysium – connective tissue that covers each whole muscle.
• Perimysium – connective tissue that covers individual bundles (fascicles) within each muscle.
• Endomysium – connective tissue that covers each muscle cell (fiber)

Skeletal Muscle Fibers
• Each muscle fiber is a single, long, cylindrical muscle cell.
  • Sarco = flesh
  • Myo = muscle
• Skeletal muscle fibers have multiple nuclei and many, many mitochondria.
• Sarcolemma = cell membrane of muscle fiber.
• Sarcoplasm = cytoplasm of muscle fiber.
• Myofibrils- thread-like bundles of myofilaments found in the sarcoplasm

Myofibrils
• Myofilaments made of protein-two types:
  – Actin-thin filaments
  – Myosin-thick filaments
• Actin and myosin filaments are arranged in repeating units: sarcomeres.
• This arrangement creates the striations seen in muscle fibers.
• Sarcomeres are the functioning unit of the muscle.

Sarcomere
• Extends from one Z-line to the next.
• I-band= light band-contains actin-thin filament
• A-band=dark band-contains myosin-thick filament
• H-zone= center of the A-band consisting of only myosin
• Z-line/disc=the ends of the sarcomere-actin connects to the z-bands
• M-line=thick filaments in the center of sacromere, linked by proteins.
Sarcoplasmic reticulum - The special type of smooth endoplasmic reticulum found in smooth and striated muscle fibers whose function is to store and release calcium ions.

Transverse Tubules (T tubules) - invaginations in the sarcolemma.
- Each T tubule lies between two cisternae (enlarged areas) of the sarcoplasmic reticulum.
- Open to the outside of the muscle fiber.
- Together they activate the muscle contraction mechanism when fiber is stimulated.

Neuromuscular Junction
- The site where the motor neuron and the muscle fiber meet.
  - Motor end plate – formed from tightly folded sarcolemma where nuclei and mitochondria are abundant.
  - The cytoplasm of the motor neuron contains numerous mitochondria and synaptic vesicles storing neurotransmitters.

Motor Units
- Composed of a motor neuron and the muscle fibers it controls.
- When stimulated, the muscle fibers of a motor unit contract all at once.
Skeletal Muscle Contraction
• Muscle contraction involves several components that result in the shortening of sarcomeres, and the pulling of the muscle against its attachments.

Role of Myosin (thick) and Actin (thin)
• Myosin consists of two twisted strands with globular “cross-bridges” projected along the strands.
• Actin is a globular protein with myosin “binding sites”
• Troponin and tropomyosin are two proteins associated with the surface of the actin filaments.

• The tail of myosin is attached to the center of the sarcomere, M-line
• The head of myosin attaches to actin if Ca is present in the sarcoplasm

Sliding Filament Theory
• During muscle contraction, the myosin cross bridge attaches to the binding site on the actin filament and bends.
  • This pulls the actin filament forward so the myosin attaches to the next binding site on the actin.
  • Like pulling up the rungs of a ladder.
  • Energy for this reaction is provided by the ATP produced by the many mitochondria in the muscle fiber.

Stimulus for Contraction
1) Motor neurons release the neurotransmitter acetylcholine from its synaptic vesicles into the synaptic cleft to initiate muscle contraction.
2) Protein receptors in the motor plate detect the neurotransmitters and a muscle impulse spreads over the surface of the sarcolemma and into the T tubules where it reaches the sarcoplasmic reticulum.
3) When the sarcoplasmic reticulum receives the muscle impulse it releases stored calcium into the sarcoplasm.
4) The high concentration of Ca interacts with the troponin and tropomyosin.
   - they move aside, exposing myosin binding sites on the actin filaments.
5) Myosin cross-bridges now bind and pull on the actin filaments – shortens sarcomeres

6) After the nervous impulse has been received by the motor plate, acetylcholinesterase (enzyme) rapidly decomposes the acetylcholine that created the muscle impulse.
   - without this, muscles would stay contracted.
7) Then, calcium is returned to the sarcoplasmic reticulum, and the linkages between myosin and actin are broken.

**Calcium and Rigor Mortis**
- **Rigor mortis**: development of rigid muscles several hours after death. Ca\(^{2+}\) leaks into sarcoplasm and attaches to myosin heads and crossbridges form but no ATP available to bind to myosin----so the cross-bridges are unable to release. Rigor ends as tissues start to deteriorate.

**Energy Sources for Contraction**
- ATP – produced by mitochondria from glucose
  - Limited supply and needs to be regenerated.
- Creatine phosphate – needed to produce ATP from ADP and phosphate
  - When ATP is abundant, creatine phosphate is created by mitochondria and when ATP is low, creatine phosphate is used to make ATP.
Oxygen Supply and Cellular Respiration

- Which process of cellular respiration produces more ATP? Aerobic or Anaerobic?
  - Aerobic – with oxygen
  - Hemoglobin – carries oxygen in RBC to cells
  - Myoglobin – pigment that stores oxygen in muscle tissue

Oxygen Debt

- During rest or moderate activity there is enough oxygen to support aerobic respiration.
- Oxygen deficiency may develop during strenuous exercise.
  - Lactic acid will accumulate because of anaerobic respiration (fermentation)
  - Lactic acid will diffuse out of muscle cells and is carried to the liver to be filtered out of blood.

- Oxygen Debt – amount of oxygen needed by liver to convert lactic acid into glucose + amount of oxygen needed by muscle cells to resynthesize ATP and creatine phosphate to their original concentrations,
- Repaying an oxygen debt may take several hours.
  - http://ltp.learnetic.com/page.php/resources/view_all?id=respiration_oxygen_debt_cell_aerobic_anaerobic_glucose_energy_protein_fat_water_carbon_dioxide_t_page_16

Muscle Fatigue [http://www.youtube.com/watch?v=LKhkvSRQZyo]

- When a muscle loses its ability to contract during strenuous exercise.
- Muscle fatigue usually arises from the build up of lactic acid in the muscle
  - A lowered pH prevents muscle from contracting.
- A muscle cramp occurs due to a lack of ATP required to return calcium ions back to the sarcoplasmic reticulum so muscle fibers can relax.
  - Muscle stays stimulated.

Muscular Responses

- Muscle fiber function can be observed by removing a single fiber and connect it to a device that stimulates the fiber and records the results.
- Myogram – recording of an electrically stimulated muscle contraction.
- Twitch – a single, short contraction involving a few motor units.

- Threshold Stimulus
  - A muscle fiber remains unresponsive to stimulation unless the stimulus is of a certain strength.
- All-or-None Response
  - When a muscle fiber contracts, it contracts to its full extent. It cannot contract partially.
- Latent Period
  - The time between when the stimulus is applied and when the muscle contracts.
  - Usually less than 2 milliseconds
Summation

- A muscle fiber receiving a series of stimuli of increasing frequency reaches a point when it is unable to relax completely and the force of individual twitches combine.
- If the sustained contraction lacks any relaxation it is called a tetanic contraction.

Recruitment of Motor Units

- An increase in the number of activated motor units within a muscle at higher intensities if stimulation is called recruitment.
- Example: when lifting a heavy item, muscle fibers will stimulate other muscle fibers around them to contract in order to lift the item.
- Summation and recruitment together can produce sustained contractions of increasing strength.
- Muscle tone is achieved by a continuous state of sustained muscle contraction.