Structure and Function of Skeletal Muscle

1. Human body contains over 400 skeletal muscles.
   - 40-50% of total body weight
2. Functions of skeletal muscle:
   - Force production for locomotion and breathing
   - Force production for postural support
   - Heat production during cold stress

Structure of Skeletal Muscle: Connective Tissue Covering

- Epimysium
  - Surrounds entire muscle
- Perimysium
  - Surrounds bundles of muscle fibers
  - Fascicles
- Endomysium
  - Surrounds individual muscle fibers

Structure of Skeletal Muscle: Microstructure

- Sarcolemma
  - Muscle cell membrane
- Myofibrils
  - Threadlike strands within muscle fibers
  - Actin (thin filament)
  - Tropomycin
  - Myosin (thick filament)

Structure of Skeletal Muscle: The Sarcomere

- Further divisions of myofibrils
  - Z-line
  - A-band
  - I-band
- Within the sarcoplasm
  - Sarcolemmal reticulum
  - Storage sites for calcium
  - Transverse tubules
  - Terminal cisternae

The Neuromuscular Junction

- Site where motor neuron meets the muscle fiber
- Separated by gap called the neuromuscular cleft
- Motor end plate
  - Pocket formed around motor neuron by sarcolemma
  - Acetylcholine is released from the motor neuron
  - Causes an end-plate potential (EPP)
  - Depolarization of muscle fiber

Motor Unit

- Single motor neuron & muscle fibers it innervates
- Eye muscles – 1:1 muscle/nerve ratio
- Hamstrings – 300:1 muscle/nerve ratio

Illustration of the Neuromuscular Junction
Muscular Contraction

- The sliding filament model
  - Muscle shortening occurs due to the movement of the actin filament over the myosin filament
  - Formation of cross-bridges between actin and myosin filaments
  - Reduction in the distance between Z-lines of the sarcomere

Cross-bridge Formation in Muscle Contraction

- Formation of cross-bridges between actin and myosin filaments

Muscle Function

- All or none law – fiber contracts completely or not at all
- Muscle strength gradation
  - Multiple motor unit summation – more motor units per unit of time
  - Wave summation – vary frequency of contraction of individual motor units

Energy for Muscle Contraction

- ATP is required for muscle contraction
  - Myosin ATPase breaks down ATP as fiber contracts

Sources of ATP

- Phosphocreatine (PC)
- Glycolysis
- Oxidative phosphorylation

Individual Fiber Types

- Fast fibers
  - Type IIb fibers
  - Fast-glycolytic fibers
- Slow fibers
  - Type I fibers
  - Slow-oxidative fibers

Properties of Muscle Fibers

- Biochemical properties
  - Oxidative capacity
  - Type of ATPase
- Contractile properties
  - Maximal force production
  - Speed of contraction
  - Muscle fiber efficiency

Sources of ATP for Muscle Contraction

- ATP: ADP & Pi + energy
- Recharging: reload cross-bridge with ATP
- Relaxation: cross-bridges “turned off”
Comparison of Maximal Shortening Velocities Between Fiber Types

Histochemical Staining of Fiber Type

Alteration of Fiber Type by Training

Endurance and resistance training
- Cannot change fast fibers to slow fibers
- Can result in shift from Type IIb to IIa fibers
  - Toward more oxidative properties

Age-Related Changes in Skeletal Muscle

Aging is associated with a loss of muscle mass
- Rate increases after 50 years of age
- Regular exercise training can improve strength and endurance
  - Cannot completely eliminate the age-related loss in muscle mass

Fiber Types and Performance

Power athletes
  - Sprinters
  - Possess high percentage of fast fibers
Endurance athletes
  - Distance runners
  - Have high percentage of slow fibers
Others
  - Weight lifters and nonathletes
  - Have about 50% slow and 50% fast fibers

Training-Induced Changes in Muscle Fiber Type

Isotonic and Isometric Contractions

Hypertrophy and Hyperplasia
- Increase in size
- Increase in number

Isometric
  - Muscle exerts force without changing length
  - Pulling against immovable object
  - Postural muscles

Isotonic (dynamically)
  - Convergent
    - Muscle shortens during force production
  - Eccentric
    - Muscle produces force but length increases

Types of Muscle Contraction

Force Regulation in Muscle
- Types and number of motor units recruited
- More motor units = greater force
- Fast motor units = greater force
- Initial muscle length
  - "Ideal" length for force generation
- Nature of the motor units neural stimulation
  - Frequency of stimulation
  - Single twitch, summation, and tetanus
**Relationship Between Stimulus Frequency and Force Generation**

**Force-Velocity Relationship**
- At any absolute force the speed of movement is greater in muscle with higher percent of fast-twitch fibers.
- The maximum velocity of shortening is greatest at the lowest force.
- True for both slow and fast-twitch fibers.

**Length-Tension Relationship in Skeletal Muscle**

**Force-Velocity Relationship**

**Force-Power Relationship**

**Receptors in Muscle**
- Muscle spindle:
  - Detect dynamic and static changes in muscle length.
  - Stretch reflex:
    - Stretch on muscle causes reflex contraction.
- Golgi tendon organ (GTO):
  - Monitor tension developed in muscle.
  - Prevents damage during excessive force generation.
  - Stimulation results in reflex relaxation of muscle.

**Simple Twitch, Summation, and Tetanus**

**Force-Power Relationship**
- At any given velocity of movement the power generated is greater in a muscle with a higher percent of fast-twitch fibers.
- The peak power increases with velocity up to movement speed of 200-300 degrees/second.
- Force decreases with increasing movement speed beyond this velocity.

**Golgi Tendon Organ**