Objectives:
The student should be able to:
1. Name the major proteins of the sarcomere that make up the thin and thick filaments.
2. Diagram how energy derived from ATP produces force through cross-bridge cycling.
3. Recognize that tension varies with the length of a muscle.
4. Name the neurotransmitter and its receptor type found at the neuromuscular junction.
5. Describe the role of the transverse tubule system.
6. State the key protein-ion interaction that initiates cross-bridge cycling.
7. List the anatomical, mechanical, and metabolic properties of slow and fast-twitch muscle fibers.
8. List two ways to produce a graded contraction.

Outline:
I. The Skeletal Muscle Motor Unit
   A. One neuron innervates multiple muscle fibers.
   B. Each muscle fiber receives innervation from only one neuron.
II. Excitation-Contraction (E-C) Coupling

A. Membrane depolarization and the action potential
   1. neurotransmitter is ACh
   2. nicotinic receptor
   3. graded depolarization spreads outside motor end-plate
   4. action potential initiates outside the end-plate

B. Transverse-tubules (T-tubules)

C. Coupling of the T-tubules and the terminal cisternae of the sarcoplasmic reticulum (SR)
   1. triad complex of dihydropyridine (DHPR) receptor and ryanodine receptor (RyR)
   2. AP sensed by DHPR
   3. RyR allows calcium release from SR

D. The calcium cycle
   1. calcium release by the SR
   2. calcium binding by the troponin complex
   3. cross-bridge cycling
   4. cptake of calcium by the SR

III. Structural Organization of the Sarcomere

A. Z line-to-Z line is one sarcomere.

B. Thick filaments, or anisotropic regions (A-bands)

C. Thin filaments, or isotropic regions (I-bands)

D. Interdigitation of the filaments
E. Dynamics of the filaments during stretch and contraction

1. width of A-bands does not change
2. sarcomere length changes
3. therefore, I-band width changes

IV. The Sliding Filament Theory of Striated Muscle Contraction

A. Myosin and the thick filament

B. Actin, tropomyosin, and troponin and the thin filament

C. Myosin-actin cross-bridge cycling and the hydrolysis of ATP
V. The Length-Tension Relationship in Skeletal Muscle

A. Active tension
   1. generated by myosin
   2. consumes energy

B. Passive tension
   1. connective tissue and intracellular structural proteins
   2. does not consume energy

C. Length-tension relationship

D. Mechanical elements of muscle

E. Physico-chemical explanation of the length-tension relationship
   1. at optimum sarcomere lengths, all myosin heads can form cross-bridges
   2. at long sarcomere lengths, some myosin heads cannot form cross-bridges
   3. at short sarcomere lengths, too much stuff is trying to occupy too little space

F. At what position in the length-tension relationship do muscles operate? Skeletal muscle operates near the optimum sarcomere length.
VI. The Twitch Mechanics of Contraction

A. Isometric contraction
   1. one action potential
   2. no shortening
   3. TPT = time-to-peak tension
   4. 1/2RT = half-relaxation time

B. Isotonic (shortening) contraction
   1. load and the contractile apparatus
   2. force-velocity relationship
   3. maximal shortening velocity - $V_{\text{max}}$

C. Muscle fiber-types and their mechanics
VII. The Graded Contraction

A. The size principle and the hierarchy of recruitment
   1. slow motor units are the first to be recruited
   2. successive motor units have faster characteristics
   3. successive motor units have more fibers

B. The force-frequency relationship for tension development
   1. summation and tetanus
   2. facilitation

C. The graded contraction

D. Feedback and integration for control of force, velocity, and position
   1. muscle spindles - located in muscle bed near motor units they feedback upon to provide information about
      a. length
      b. velocity
   2. Golgi tendon organs - located in tendon junctions of motor units the feedback upon to provide force and change in force information
VIII. Energy and Fatigue

A. Turnover of ATP

1. velocity of contraction is related to ATP consumption
2. limited ATP stores are replenished by creatine kinase

B. Muscle fiber-types and their metabolism

1. glycogenolytic metabolism
2. oxidative metabolism

C. Rigor

IX. Summary - The Spectrum of Motor Units and Their Recruitment

X. Adaptation - What do Astronauts and Hospital Patients Have in Common?

A. Exercise disrupts the milieu interieur

1. second messenger activity
2. metabolism

B. Adaptational responses to training and detraining

1. acute responses - economy
2. chronic responses
   a. resistance work
   b. endurance work
   c. bedrest and hypokinesia

C. Muscle soreness

**ATP Turnover**

**Muscle Fiber Metabolism**

<table>
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**Acute Responses to Exercise Favor Economy**

**Chronic Responses Favor Economy**

<table>
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<th>Model</th>
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