

TOPIC 11: SKELETAL MUSCLE: MOLECULAR BASIS OF CONTRACTION

I. Introduction to All Muscles

- A. Movements in body
 1. cell components move within cell during cell division
 2. white blood cells can propel themselves through body
 3. muscle cells: contraction specialists involved in events ranging from propulsion of food through GI tract to propulsion of whole body (walking)
- B. Three types of muscle (Fig 12.32)
 1. Skeletal: striated (alternating light and dark bands) and voluntary (innervated by somatic nervous system)
 2. Cardiac: striated, involuntary (innervated by autonomic nervous system)
 3. Smooth: unstriated, involuntary (innervated by autonomic nervous system)
- C. Muscles respond to *electrical* signals to convert *chemical* energy (ATP) to *mechanical* energy that can act on environment (e.g., lifting)
- D. Controlled contraction of muscles allow
 1. movement of body or body parts through external environment (walking)
 2. manipulation of objects in external environment (writing)
 3. propulsion of substances through hollow organs (blood flow, digestion)
 4. emptying contents of organs to environment (e.g., urination, giving birth)
- E. Muscle is largest group of tissues in body, & makes up 40 to 50 % of body mass.

II. Structure of Skeletal Muscle

- A. Organization of an entire muscle
 1. A single skeletal muscle is composed of many muscle fibers (a muscle fiber is the same thing as a muscle cell) lying parallel to each other and bundled together by connective tissue (Fig 12.1 & 12.2). A muscle may be innervated by many motor neurons.
 2. Motor Unit: 1 motor neuron plus all the fibers it innervates (Fig 11.14)
 - a) Each motor neuron innervates *numerous* muscle fibers distributed throughout the muscle
 - b) Each muscle fiber is innervated by *only one* motor neuron
 - c) When a motor neuron is activated, *all fibers* that it innervates contract simultaneously
 - d) One motor unit activation results in a weak contraction of muscle
 - e) As more motor units recruited (i.e. stimulated) the contraction gets stronger and stronger
 - f) Number of muscle fibers per motor unit, and the number of motor units per muscle, vary widely
 - g) Asynchronous recruitment occurs to prevent fatigue
 - (1) alternation of motor unit activity, like factory shift workers
 - (2) only possible during submaximal contractions
- B. Muscle fiber structure (Fig 12.1)
 1. extends the length of the muscle (up to .75 meter, or 2.5 feet. long),
 2. has multiple nuclei and many mitochondria
 3. composed of many **myofibrils**, each of which extends the length of the muscle fiber.
- C. Myofibril structure (relaxed, Figs 12.2 & 12.3)

1. Composition of a myofibril
 - a) thick filaments, ~ 1.6 μm long
 - b) thin filaments, ~ 1.0 μm long
2. Organization of myofibril (Fig 12.3)
 - a) A band
 - (1) Stacked set of thick filaments plus portions of thin filaments that overlap both ends of thick filaments
 - b) H Zone
 - (1) light area in A band where thin filaments don't reach
 - c) I band
 - (1) Portion of thin filaments that do not project into A band
 - d) Z line
 - (1) Cytoskeleton protein that runs vertically through middle of I band & connects thin filaments of adjoining sarcomeres
 - e) Sarcomere
 - (1) Area between two Z lines
 - (2) Is the functional unit of skeletal muscle, (i.e. smallest component that can perform all the functions of that organ), so sarcomere is smallest contractile unit of muscle
 - f) M line
 - (1) Supporting proteins that hold thick filaments together vertically; extends vertically down the middle of the A band in the H zone
 - g) Cross bridges
 - (1) Extend from thick filaments to thin filaments
 - (2) Six thin filaments surround every thick filament; the thick filament projects cross bridges to each of the 6 thin filaments
- D. Thick filament structure (Fig 12.5)
 1. Thick filament composed of
 - a) **myosin molecules** lying lengthwise parallel to each other
 - b) half are oriented in one direction
 - c) half are oriented in other direction
 2. Myosin molecule structure
 - a) Two golf club shaped subunits with tails intertwined and globular heads (**myosin heads also called cross bridges!**) projecting out at one end
 - b) Each head contains an actin binding site and a myosin ATPase site
- E. Thin filament structure (Fig 12.4)
 1. Actin
 - a) molecules are spherical in shape
 - b) each has a myosin binding site
 - c) backbone of thin filament formed by two chains of actin molecules wrapped around each other, like two chains of pearls
 2. Tropomyosin
 - a) Threadlike proteins that lie end to end along actin spiral

- b) Covers myosin binding sites on actin
 - 3. Troponin
 - a) Fastens down each end of the tropomyosin molecules, holding them in place over myosin binding site
 - F. Transverse Tubules (T Tubules) (Fig 12.2)
 - 1. Part of surface membrane of muscle fiber that dips into fiber at junction of A and I bands
 - G. Sarcoplasmic Reticulum (Fig 12.2)
 - 1. Modification of endoplasmic reticulum
 - 2. Surrounds each myofibril with separate segments encircling each A and I band
- III. Molecular Basis of Contraction: The Sliding Filament Model
- A. Overview (Fig 12.8 & 12.9)
 - 1. Ach released by terminal button of motor neuron & binds to receptors on motor end plate
 - 2. Ach binding on motor end plate causes End Plate Potential which causes an Action Potential to propagate down membrane and down T Tubules into muscle cell
 - 3. AP in the T Tubule causes sarcoplasmic reticulum to release Ca^{++}
 - 4. Released Ca^{++} bind to troponin on actin filaments, which causes tropomyosin to move aside and expose myosin binding sites on the actin molecules
 - 5. Cross bridge cycling: myosin cross bridges bind to actin and stroke forward (powered by ATP) pulling actin toward center of sarcomere
 - 6. Ca^{++} actively taken up by SR when no more AP
 - 7. With Ca^{++} no longer bound to troponin, tropomyosin returns to blocking position over myosin binding site on actin.
 - B. Cross bridge cycle in detail (Fig 12.7)
 - 1. ATP broken into ADP and P_i by ATPase on myosin head; the head holds onto the ADP and P_i , and is energized and cocked in the "ready" position
 - 2. In presence of Ca^{++} , myosin binding site on actin is uncovered, and myosin head binds to actin
 - 3. On contact of myosin and actin, ADP and P_i released and myosin head strokes forward
 - 4. Fresh ATP binds to myosin, link with actin broken, and return to step 1.
 - 5. This continues, and myosin heads ratchets actin along (Fig 8-9).
 - 6. When Ca^{++} removed, no more heads binding actin, so it slides back into original place = relaxation
 - C. Changes in Myofibril during contraction (Fig 12.6)
 - 1. Sarcomere shortens
 - 2. I band shortens
 - 3. H zone gets smaller
 - 4. A band same width