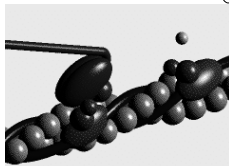


# Muscle Contraction




---

---

---

---

---

---

---

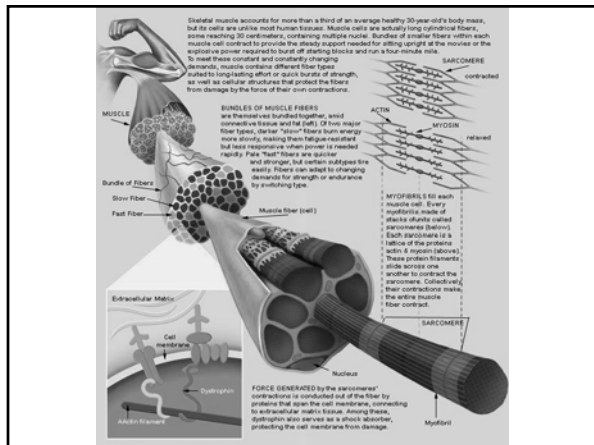
---

---

---

---

---




---

---

---

---

---

---

---

---

---

---

---

---

## Levels of Muscle Structure

- Muscle
- Muscle Bundle
- Muscle Fiber (myofiber)
- Myofibrils
- Myofilaments

The Motor Unit

Motor neuron, Branches of motor neurons, Myofibrils, Muscle fiber

---

---

---

---

---

---

---

---

---

---

---

---

## Muscle



---

---

---

---

---

---

---

---

## Muscle Bundle

- Contains 10-20 myofibers
- Encased by perimysium
- Can see with the naked eye

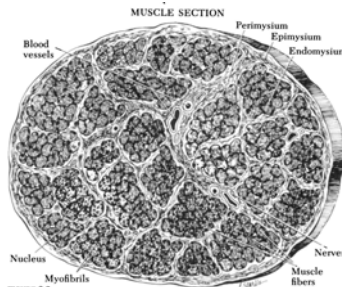


FIGURE 3-3 Drawing of a skeletal muscle in cross section showing muscle fibers, bundle arrangement, surrounding connective tissues, nerves, and blood vessels. [Modified from J. E. Couch, *Functional Human Anatomy*, 2nd ed. 1972. Lea & Febiger, Philadelphia.]

---

---

---

---

---

---

---

---

## Myofiber (Muscle fiber)

- Individual muscle cell
- Multinucleated
- Encased by endomysium
- Cell wall: sarcolemma

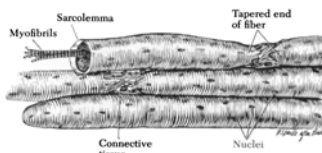


FIGURE 3-4 Drawing of skeletal muscle fibers showing structural features, and their longitudinal orientation. [Aber M. Bridel, *Johns Hopkins Hosp. Bull.* 61:205, 1937. © The Johns Hopkins University Press.]

---

---

---

---

---

---

---

---

## Myofibrils

- Embedded in sarcoplasm
- Mitochondria located between myofibrils

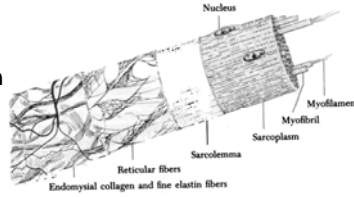


FIG. 2.9. DIAGRAMMATIC SKETCH OF A MUSCLE FIBER

---

---

---

---

---

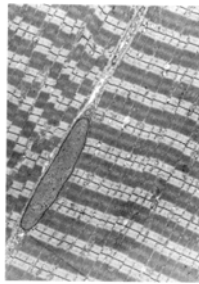
---

---

---

## Myofibrils

- Comprised of repeating units: sarcomeres
  - A band
  - I band
  - Z disk
  - H zone
  - Pseudo-H zone




---

---

---

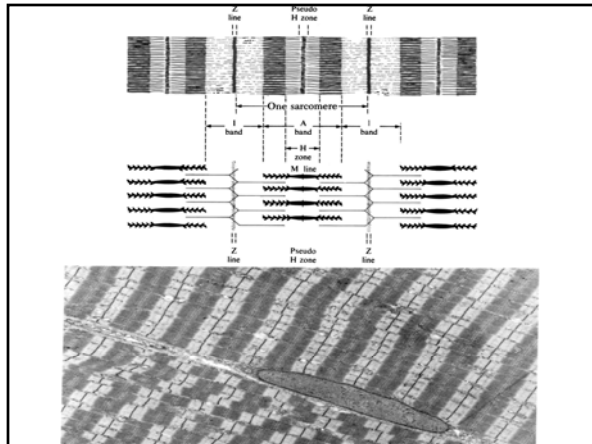
---

---

---

---

---




---

---

---

---

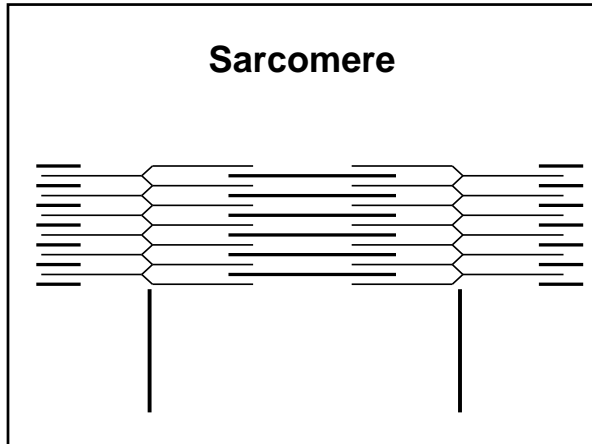
---

---

---

---

## Sarcomere




---



---



---



---



---

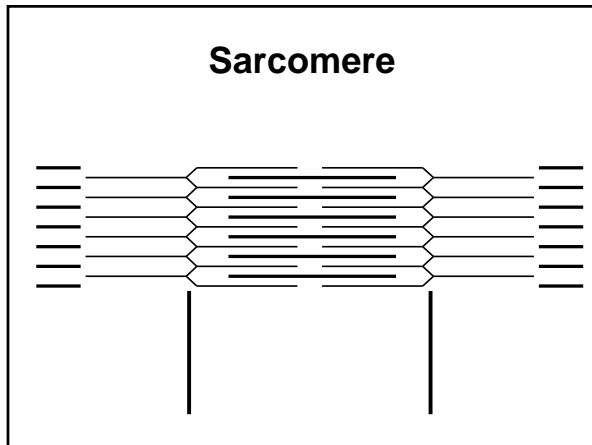


---



---

## Sarcomere




---



---



---



---



---



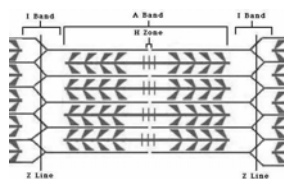
---



---

## Myofilaments

- **Contractile Proteins**
  - Myosin
  - Actin
- **Regulatory Proteins**
  - Tropomyosin
  - Troponin
- **Structural Proteins**
  - Z – Line Proteins




---



---



---



---



---



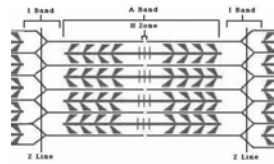
---



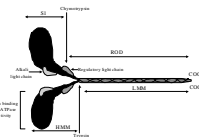
---

## Contractile Proteins

- **Myosin**
  - 70 – 80% of the total protein
  - Thick filament
  - Burns the ATP for muscle contraction
  - Myosin head moves back and forth to perform a muscle contraction



Myosin & Its Fragments




---

---

---

---

---

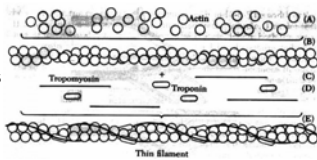
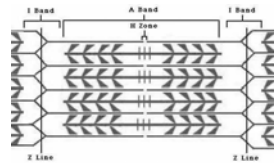
---

---

---

## Contractile Proteins

- **Actin**
  - 20% of the myofibrillar protein
  - Thin Filament
  - Globular protein (G-protein)
  - Arranged like a twisted pearl necklace (F-protein)
  - Myosin head attaches to the Actin




---

---

---

---

---

---

---

---

## Regulatory Proteins

- Regulate contraction and the speed of contraction
- Tropomyosin
- Troponin

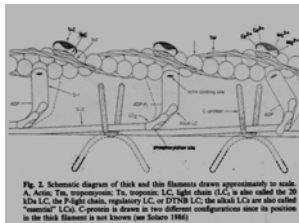


Fig. 2. Schematic diagram of thick and thin filaments drawn approximately to scale. A, Actin; Ts, tropomyosin; Tn, troponin; LC, light chain (LC, is also called the 20 kDa LC, the flight chain, regulatory LC, or DTN1 LC); the small LCs are also called "essential" LCs). C, troponin is drawn in two different configurations since its position in the thick filament is not known (see Sellers 1984).

---

---

---

---

---

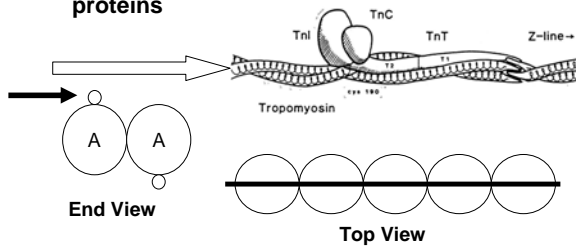
---

---

---

## Regulatory Proteins

- **Tropomyosin**
  - Thin protein that lays around the Actin proteins



---

---

---

---

---

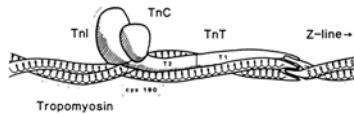
---

---

---

## Regulatory Proteins

- **Troponin**
- **3 Subunits**
  - **TnT**
    - Binds tropomyosin
  - **TnI**
    - Inhibitory subunit
  - **TnC**
    - Ca<sup>2+</sup> binding subunit



---

---

---

---

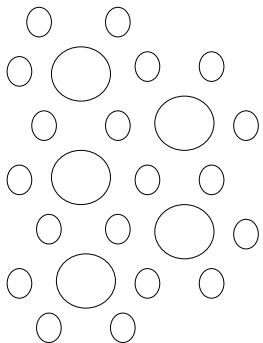
---

---

---

---

## 3 Dimensional



---

---

---

---

---

---

---

---

## How does all this fit together?

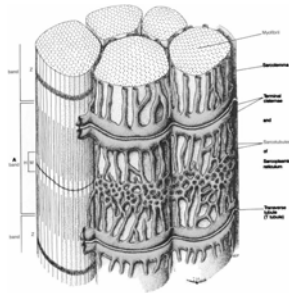


Fig. 10-16. Diagram of part of a mammalian skeletal muscle fiber, showing the arrangement of myofibrils in parallel. In mammalian skeletal muscle, two transverse T-tubules supply a sarcomere. Each T-tubule is situated in the junction between an A-band and I-band. When it is associated with two terminal cisternae of sarcoplasmic reticulum, terminal cisternae form a sarcoplasmic reticulum. The sarcoplasmic reticulum is a network of tubular structures in the sarcoplasm. The space between two adjacent terminal cisternae is called a sarcomere. (Courtesy of C. F. Lamb.)

---

---

---

---

---

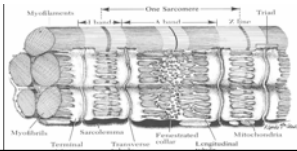
---

---

---

## More Structural Stuff

- Sarcolemma – membrane around the myofibril; sits just under the endomysium
- Sarcoplasmic Reticulum
- T – tubules or Transverse Tubules
- Terminal Cisternae




---

---

---

---

---

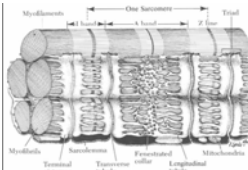
---

---

---

## More Structural Stuff

- Sarcoplasmic Reticulum
  - Surrounds each myofibril
  - Stores Calcium, needed for contraction
- T – tubules and Terminal Cisternae transport Ca to cytosol & transmit nerve impulse




---

---

---

---

---

---

---

---

**We've laid the ground work, let's talk about muscle contraction**

**“Sliding Rod Theory” Hanson and Huxley 1955; Huxley 1965, 1972; Huxley and Hanson, 1960**

---

---

---

---

---

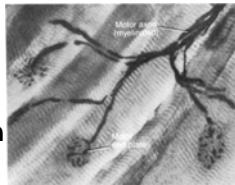
---

---

---

### **Muscle Contraction**

- A signal travels down a nerve
- Attached to individual muscle cells
- The signal is passed on the Sarcolemma
- The Sarcolemma depolarizes



**Fig. 15-12.** Photomicrograph showing the motor end plates on skeletal muscle fibers (stained with gold chloride).

---

---

---

---

---

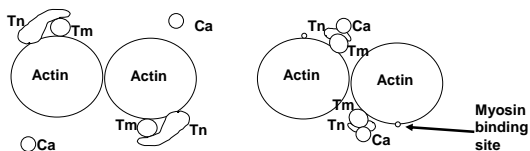
---

---

---

### **Muscle Contraction**

- The depolarization causes the SR to release Ca into the cytosol
- The Ca will bind with troponin (Tn)
- This causes a shift in the troponin tropomyosin (Tm) complex



---

---

---

---

---

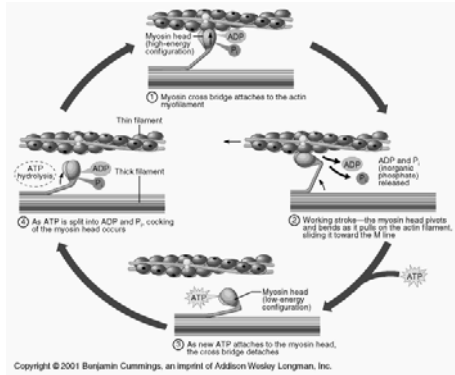
---

---

---



## The ATPase activity of Myosin




---

---

---

---

---

---

---

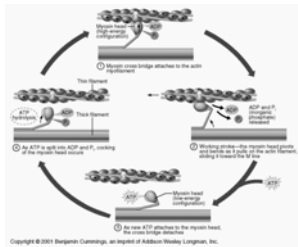
---

---

---

## The ATPase activity of Myosin

- ATP (Adenosine Triphosphate) bind to the Myosin head
- ATP hydrolysis to ADP + Pi “cocks” the Myosin head




---

---

---

---

---

---

---

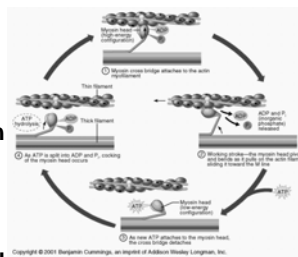
---

---

---

## The ATPase activity of Myosin

- The Myosin head attaches to the exposed binding site on Actin
- Weak bond
- Pi leaves the Myosin head causing the “Power Stroke”
- ADP is released causing a strong Myosin – Actin bond




---

---

---

---

---

---

---

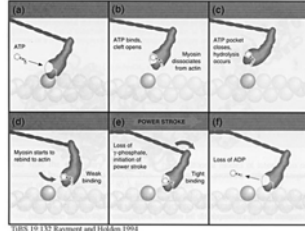
---

---

---

## The ATPase activity of Myosin

- ATP re-attaches to the Myosin head causing the head to release from the Myosin – Actin binding site




---



---



---



---



---



---



---



---

## Let's put it all together

- 1.) An impulse travels down a nerve to a muscle cell
- 2.) The nerve impulse is transferred to the Sarcolemma of a muscle cell
- 3.) The Sarcolemma depolarized causing the Sarcoplasmic Reticulum to release Ca into the cytosol of the cell

---



---



---



---



---



---



---



---

## Let's put it all together

- 4.) The Ca binds to Troponin on the Troponin – Tropomyosin complex
- 5.) The Tn – Tm complex shifts to the groove of the Actin exposing the Actin – Myosin binding site
- 6.) ATP has bound with the Myosin head releasing it from the previous contraction

---



---



---



---



---



---



---



---

## Let's put it all together

- 7.) Myosin hydrolyzes the ATP to ADP + Pi, “cocking” the Myosin head
- 8.) Myosin attaches to Actin forming a weak bond
- 9.) Pi is released causing the “power stroke”
- 10.) ADP is released forming a tight rigor bond of Actin and Myosin



---

---

---

---

---

---

---

---

<http://www.tvermilye.com/pmwiki/pmwiki.php?n=Animation.Video12>

---

---

---

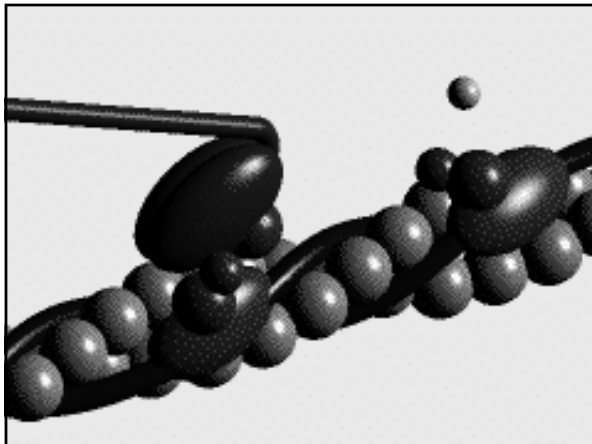
---

---

---

---

---



---

---

---

---

---

---

---

---

**What makes these guys so strong?**



---

---

---

---

---

---

---

---

**What makes those guys strong is the same that makes him strong!**



---

---

---

---

---

---

---

---

**Or, Who's Stronger??**



---

---

---

---

---

---

---

---

**See ya this afternoon**

---

---

---

---

---

---

---

---