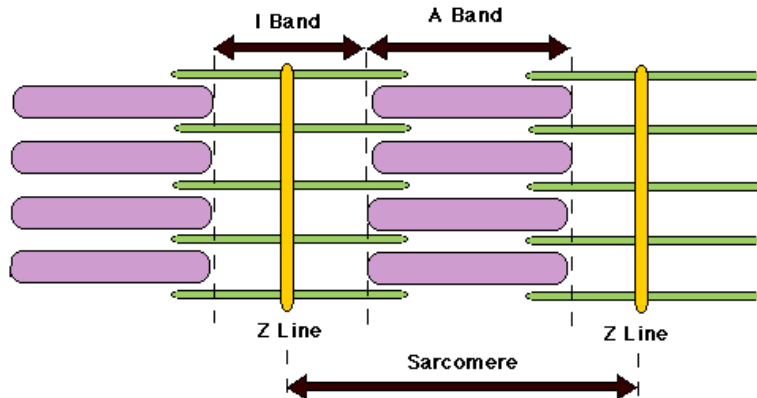


# Notes: Muscle Contraction

## The Basic Unit of Muscle Contraction is the Sarcomere.

- Skeletal and cardiac muscle are striated (smooth muscle has a similar contractile mechanism but is not so highly organized and does not show striations)
- The striations are caused by alignment of bands: the most prominent are the A and I bands and the Z line
- The unit between 2 Z lines is called the sarcomere

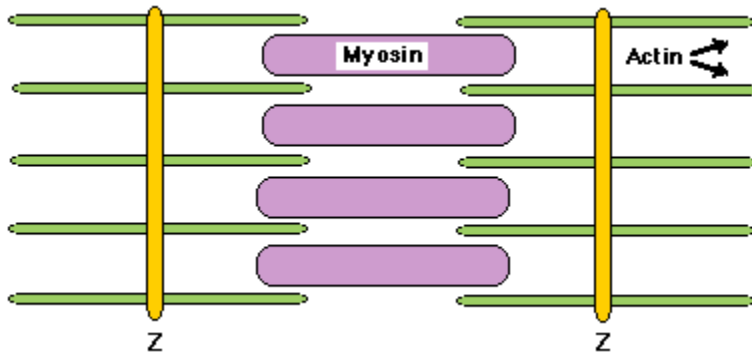


- The figure shows the structure of the bands in terms of the major proteins, actin & myosin: see below
  - In the A band the 2 proteins overlap
  - The I band contains only the actin protein
- When muscle contracts the sarcomere shortens and the Z lines move closer together
- The sarcomere is the basic unit of contraction; with electrodes it is possible to stimulate a single sarcomere and make it contract

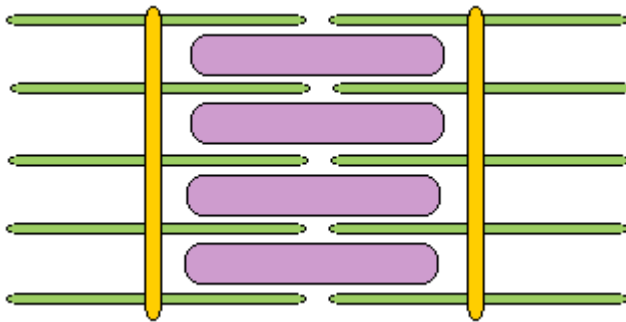
## When Muscle Contracts Protein Filaments Slide Together

- Electron microscopy combined with chemical experiments show that muscle is composed of 2 contractile proteins:
  - a) Thin filaments: actin, attached to Z line, found in both A and I bands
  - b) Thick filaments: myosin, found in A band

- Relaxed state:



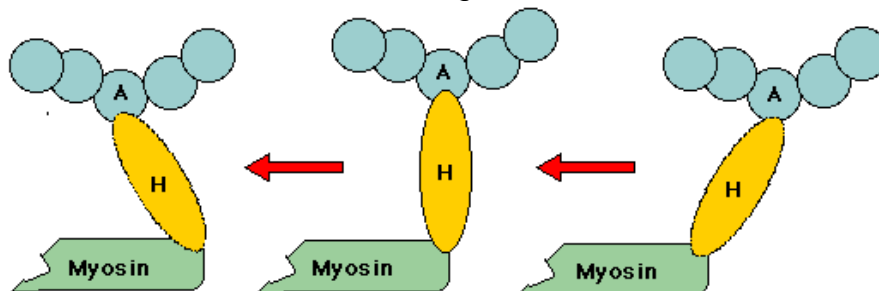
- When muscle contracts the actin filaments slide into the A band, overlapping with myosin



- Notice what happens when muscle contracts:
  - a) the Z lines move closer together
  - b) the I band becomes shorter
  - c) the A band stays at the same length
- This is called the "sliding filament" model of muscle contraction
- Maximum contraction of the sarcomere is about 30%

### Muscle Contracts When Myosin Crossbridges Attach to Actin and the Molecule Bends

- The filaments slide together because myosin attaches to actin and pulls on it
  - Myosin head (H) attaches to actin filament (A), forming a crossbridge
  - After the crossbridge is formed the myosin head bends, pulling on the actin filaments and causing them to slide:



- Muscle contraction is a little like climbing a rope. The crossbridge cycle is: grab - > pull -> release, repeated over and over

### **ATP is Required for Both Contraction and Relaxation of Muscle**

- ATP is the energy supply for contraction
- It is required for the sliding of the filaments which is accomplished by a bending movement of the myosin heads
- It is also required for the separation of actin and myosin which relaxes the muscle
- When ATP runs down after death muscle goes into a state of rigor mortis

### **The Trigger for Muscle Contraction is Ca<sup>2+</sup>**

- A sudden inflow of Ca is the trigger for muscle contraction
- In the resting state the protein tropomyosin winds around actin and covers the myosin binding sites
- The Ca binds to a second protein, troponin, and this action causes the tropomyosin to be pulled to the side, exposing the myosin binding sites
- With the sites exposed muscle will contract if ATP is present

### **In Muscle Ca<sup>2+</sup> is Stored in the Sarcoplasmic Reticulum**

- Storage of Ca:
  - The Ca which causes muscle contraction is stored in the sarcoplasmic reticulum (this is a specialized version of the endoplasmic reticulum)
  - The SR has a powerful Ca pump which concentrates Ca
- Release of Ca:
  - Skeletal muscle is stimulated by nerves which contact muscle through a [neuromuscular junction](#).
  - The nerve releases acetylcholine and generates a muscle action potential
  - The action potential travels down the T-tubule and causes the sarcoplasmic reticulum (SR) to release Ca
- After the contraction the Ca must be rapidly pumped back into the SR so the muscle can contract again

### **In Cardiac (Heart) and Smooth Muscle Special Junctions Help Spread the Excitation from One Cell to Another**

- In skeletal muscle each fiber (cell) can contract independently
- In cardiac and smooth muscle the cells are interconnected by special junctions- intercalated disks in cardiac and gap junctions in smooth muscle
- This spreads the excitation from one cell to another and causes cardiac and most smooth muscle to contract as a unit
- Cardiac muscle beats spontaneously, even if all nerves to the heart are cut. The nerves do speed up or slow down the heart beat, however

## Cutting the Nerve to a Muscle Will Cause it to Degenerate

- A healthy skeletal muscle requires stimulation
- If nerves to a muscle are cut or badly damaged the muscle will degenerate

## A Comparison of Skeletal, Cardiac and Smooth Muscle :

Property	Skeletal Muscle	Cardiac Muscle	Smooth Muscle
Striations?	Yes	Yes	No
Relative Speed of Contraction	Fast	Intermediate	Slow
Voluntary Control?	Yes	No	No
Membrane Refractory Period	Short	Long	
Nuclei per Cell	Many	Single	Single
Control of Contraction	Nerves	Beats spontaneously but modulated by nerves	Nerves Hormones Stretch
Cells Connected by Intercalated Discs or Gap Junctions?	No	Yes	Yes

(<http://hometown.aol.com/bio50/LecNotes/lecnot13.html>)