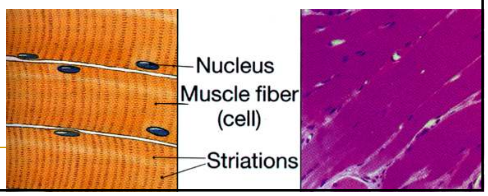
Chapter 12: Muscles

Review muscle anatomy (esp. microanatomy of skeletal muscle)



Terminology:

- **sarcolemma**
- **t-tubules**
- **sarcoplasmic reticulum**
- **myofibers, myofibrils, myofilaments**
- **sarcomere**

More Terminology:

- **Tension**
- **Contraction**
- **Load**
- **Excitation-contraction coupling**
- **Rigor**
- **Relaxation**

Anatomy

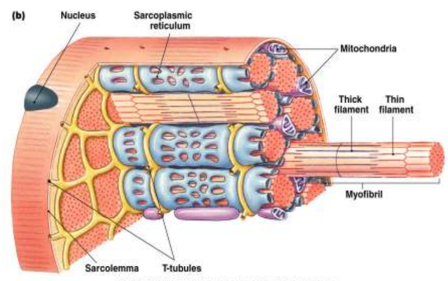


Fig 12-3

More Anatomy

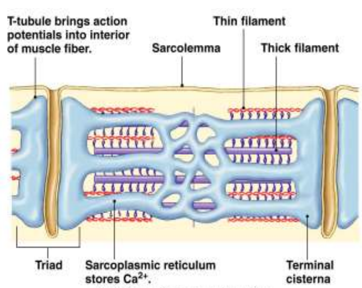


Fig 12-3

Myofibrils = Contractile Organelles of Myofiber

Contain 6 types of protein:

- **Actin**
- **Myosin**

Contractile

- **Tropomyosin**
- **Troponin**

Regulatory

- **Titin**
- **Nebulin**

Accessory

Fig 12-3 c-f

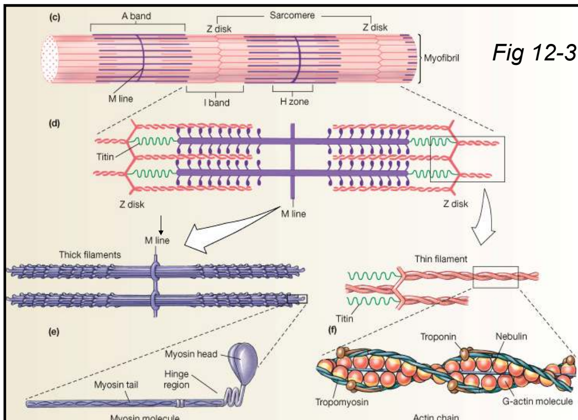


Fig 12-3

Titin and Nebulin

- **Titin**: **biggest protein known (25,000 aa); elastic!**
  - *Stabilizes position of contractile filaments*
  - *Return to relaxed location*
- **Nebulin: inelastic giant protein**
  - *Alignment of A & M*

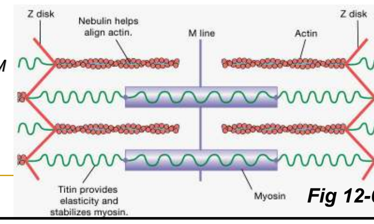
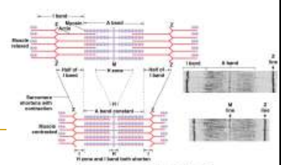


Fig 12-6

Sliding Filament Theory p 403

- **Sarcomere = unit of contraction**
- **Myosin "walks down" an actin fiber towards Z-line**
  - **? - band shortens**
  - **? - band does not shorten**
- **Myosin = motor protein:**

chemical energy → mechanical energy of motion



Changes in a Sarcomere during Contraction

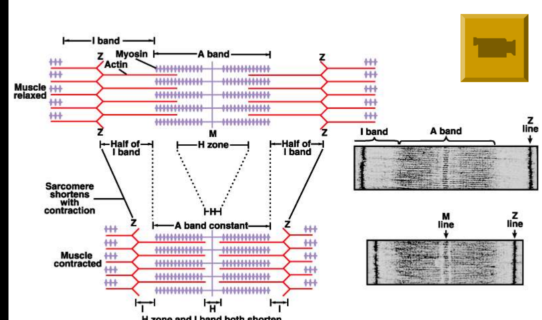
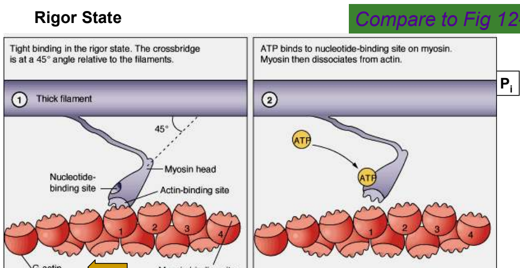


Fig 12-8

The Molecular Basis of Contraction

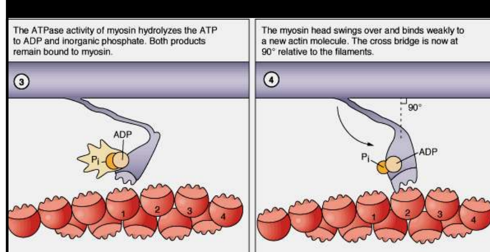
Rigor State

Compare to Fig 12-9

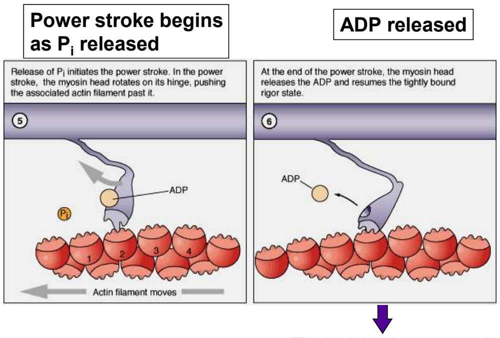


- Tight binding between G-actin and myosin
- No nucleotide bound

ATP binds ⇒ dissociation



Relaxed muscle state when sufficient ATP



Tight binding to actin

Myosin crossbridge movement pushes actin

Regulation of Contraction by Troponin and Tropomyosin

- **Tropomyosin blocks myosin binding site** (weak binding possible but no powerstroke)
- **Troponin controls position of tropomyosin and has Ca^{2+} binding site**
  - **Ca^{2+} present: binding of A & M**
  - **Ca^{2+} absent: relaxation**

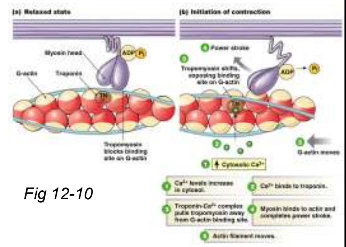


Fig 12-10

Rigor mortis

Joint stiffness and muscular rigidity of dead body

Begins 2 – 4 h post mortem. Can last up to 4 days depending on temperature and other conditions

Caused by leakage of Ca^{2+} ions into cell and ATP depletion

Maximum stiffness ~ 12-24 h post mortem, then?

Initiation of Contraction

Excitation-Contraction Coupling explains how you get from AP in axon to contraction in sarcomere

ACh released from somatic motor neuron at the Motor End Plate

⬇

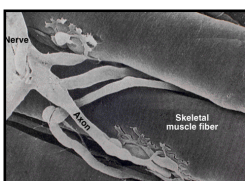
AP in sarcolemma and T-Tubules

⬇

Ca^{2+} release from sarcoplasmic reticulum

⬇

Ca^{2+} binds to troponin



Details of E/C Coupling

Nicotinic cholinergic receptors on motor end plate
= Na^+/K^+ channels

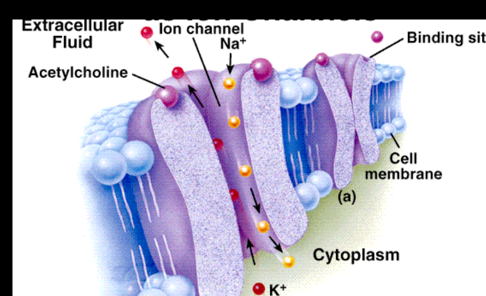
⟹ Net Na^+ entry creates EPSP

⟹ AP to T-tubules

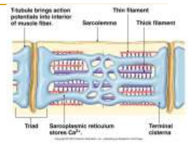
⟹ DHP (dihydropyridine) receptors in T-tubules sense depolarization

Fig 12-11

Nicotinic Cholinergic Receptors



Excitation-Contraction Coupling



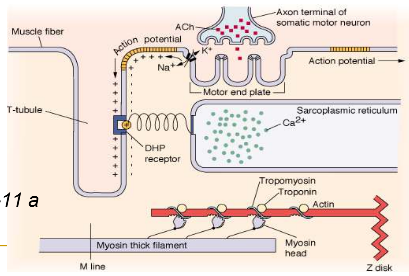


Fig 12-11 a

DHP (dihydropyridine) receptors open Ca^{2+} channels in t-tubules

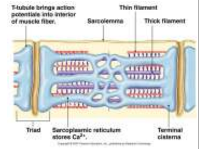
Intracytosolic $[Ca^{2+}]$ ↑

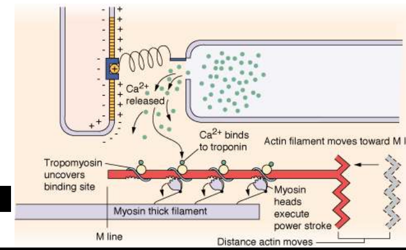
Contraction

Ca^{2+} re-uptake into SR

Relaxation

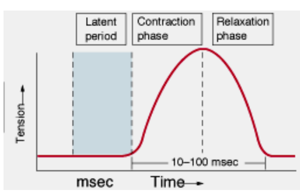
[redacted]





Muscle Contraction Needs Steady Supply of ATP

- **Where / when is ATP needed?**
- **Only enough ATP stored for 8 twitches**
  - **Phosphocreatine may substitute for ATP**



Twitch = single contraction relaxation cycle

Where does all this ATP come from?

- **Phosphocreatine: backup energy source**

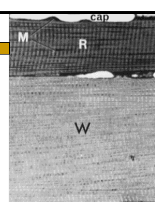
phosphocreatine + ADP $\xrightarrow{C(P)K}$ creatine + ATP

- **CHO: aerobic and anaerobic resp.**
- **Fatty acid breakdown always requires O_2 – is too slow for heavy exercise**
  - **Some intracellular FA**

Slow-twitch Fibers

Oxidative only

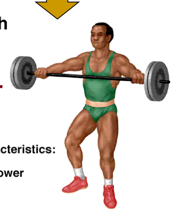
Muscle fiber characteristics:
- Is aerobic
- Has steady power
- Has endurance



Muscle Fiber Classification

Fast-twitch Fibers

Oxidative or glycolytic



Muscle fiber characteristics:
- Is anaerobic
- Has explosive power
- Fatigues easily

Muscle Adaptation to Exercise

(not in book)

Endurance training:
- More & bigger mitochondria
- More enzymes for aerobic respiration
- More myoglobin

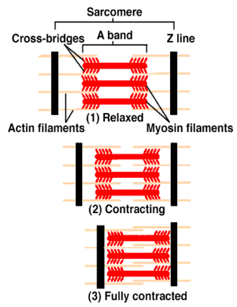
no hypertrophy

Resistance training:
- More actin & myosin proteins & more sarcomeres
- More myofibrils

muscle hypertrophy

Muscle Tension is Function of Fiber Length

- **Sarcomere length reflects thick, thin filament overlap**
- **Long Sarcomere: little overlap, few crossbridges ⇒ weak tension generation**
- **Short Sarcomere: Too much overlap limited crossbridge formation ⇒ tension decreases rapidly**

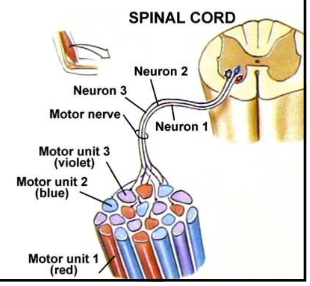


Force of Contraction (all-or-none)

- **Increases With**
  - **muscle-twitch summation**
  - **recruitment of motor units**

Mechanics of body movement covered in lab only

Fig 12-17



Smooth muscle

- A few differences
  - Innervation by varicosities
  - Smaller cells
  - Longer myofilaments
  - Myofilaments arranged in periphery of cell
- Cardiac muscle contraction covered later