



Advanced Meats Muscle Ultrastructure



Muscle Types and Their Characteristics



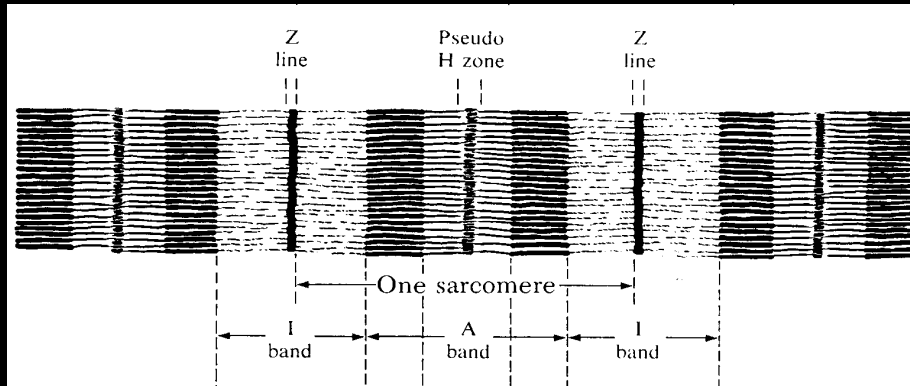
- Muscles are attached to bone
- Veins and arteries enter and exit muscle
- Locomotion, chewing, breathing
- Support
- 35-65% of carcass weight
- Vary in size, shape, and function



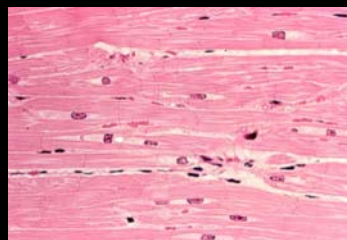
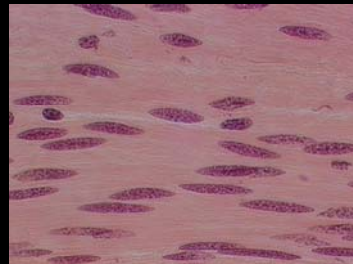
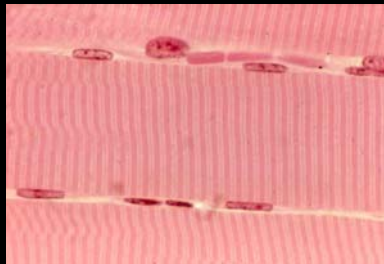
Muscle Types and Their Characteristics



	SKELETAL	SMOOTH	CARDIAC
•METHOD OF CONTROL	VOLUNTARY	INVOLUNTARY	INVOLUNTARY
•BANDING PATTERN	STRIATED	NON-STRIATED	STRIATED
•NUCLEI/CELL	MULTI	SINGLE	SINGLE



Muscle Types and Their Characteristics



Muscle Composition



- Water (75%)
- Protein (19%)
 - Myofibrillar (11.5%), Sarcoplasmic (5.5%), Stromal (2%)
- Lipid (2.5%)
- Carbohydrate (1.2%)
- Soluble (non-protein) (1.65%)
- Inorganic (.65%)
- Vitamins (<1%)



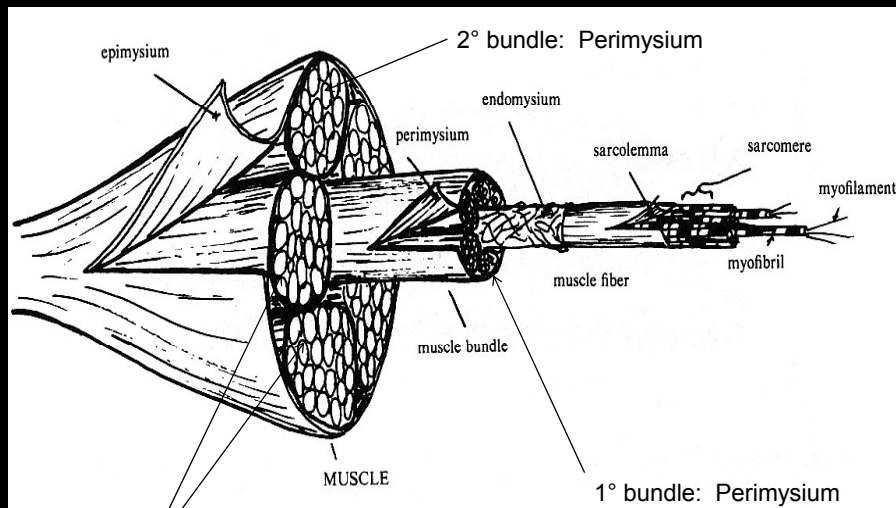
Muscle Organization



- Muscle: Epimysium
- Tertiary bundle: Perimysium, several 2° bundles
- Secondary bundle: Perimysium, 3-20 1° bundles
- Primary bundle: Perimysium, 20-40 fibers
- Muscle Fiber: Endomysium, 10-100µm
- Myofibril
- Myosin
- Actin



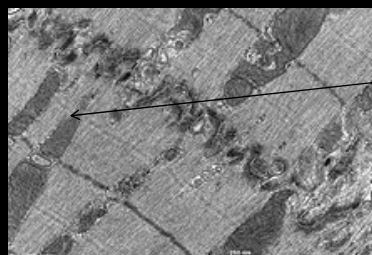
Connective Tissue



Organelles of Skeletal Muscle



- Muscle Fibers: cellular unit of muscle
 - *Can't survive with one nucleus – multinucleated*
 - *200-300 nuclei/cell*
 - *Do not run the entire length of the muscle (not tendon to tendon)*
 - *Fibers are interdigitated*



interdigitations



Organelles of Skeletal Muscle



- **Sarcolemma** – cell membrane of skeletal muscles

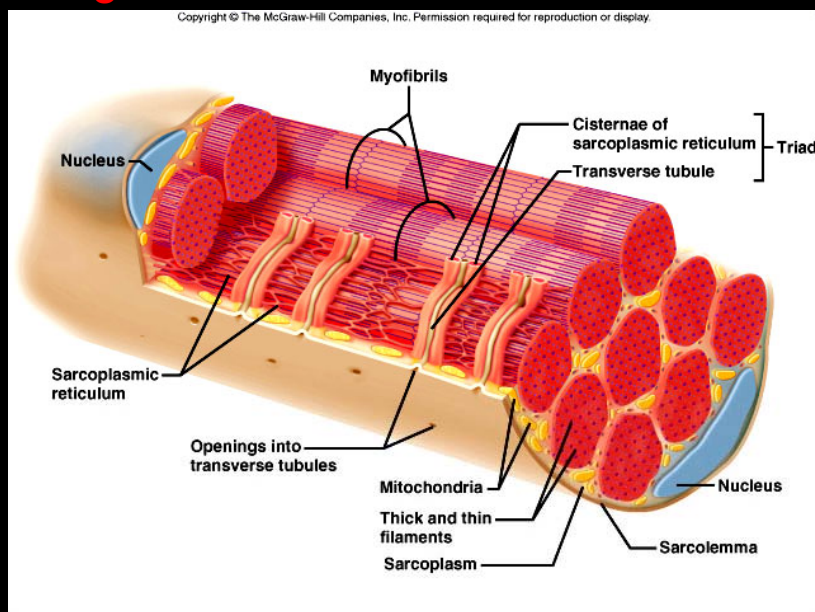
- *Surrounds a muscle fiber*
- *Composed of protein and lipids*
- *Elastic*
- *Located periodically along the length, around the entire circumference, are invaginations of the sarcolemma that form a network of tubules called transverse tubules (T tubules)*
- *Motor nerve endings terminate on the sarcolemma at the myoneural junction*
 - Myoneural junctions form a small mound – entire structure is called motor end plate.



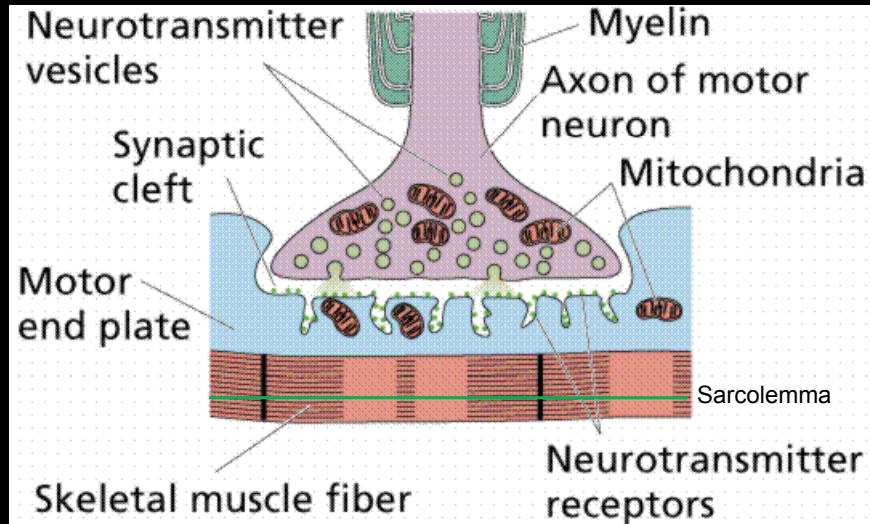
Organelles of Skeletal Muscle



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Organelles of Skeletal Muscle



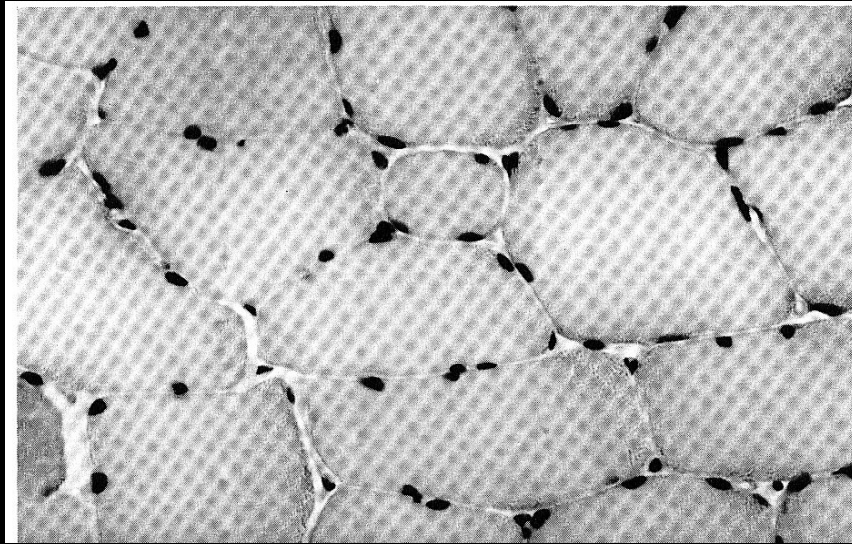
Organelles of Skeletal Muscle



- Sarcoplasm – cytoplasm of muscle fibers
 - *Intracellular substance which suspends all organelles*
 - *75 to 80% H₂O; contains lipid droplets, glycogen granules, ribosomes, numerous proteins, NPN compounds*
- Nuclei
 - *Multinucleated*
 - *Number per fiber is not constant*
 - *Higher numbers near tendon attachments and motor end plates*
 - *Ellipsoidal in shape, axis is oriented parallel to long axis of fiber*



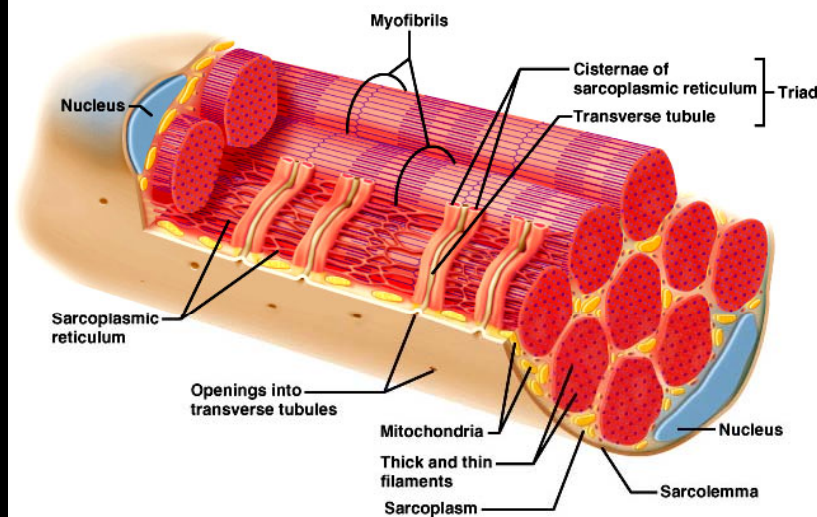
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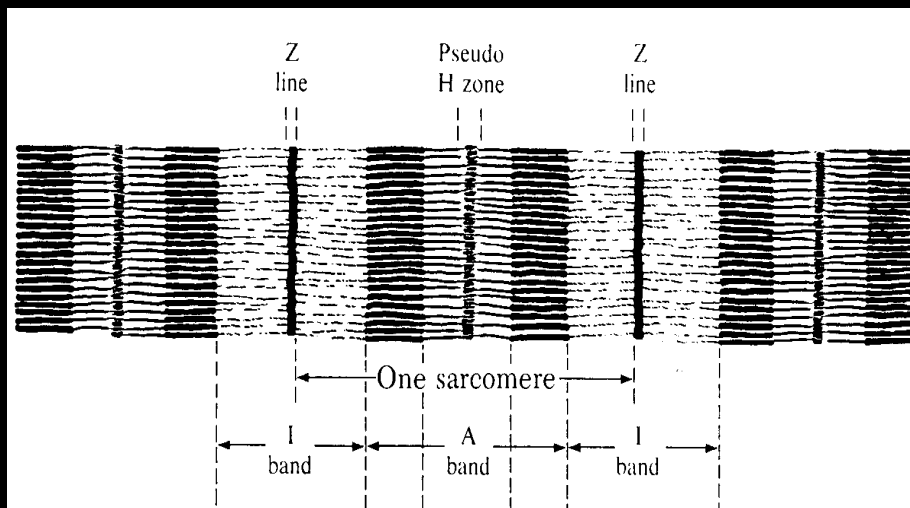


- Myofibrils

- Long, thin, cylindrical rods, $2.3\ \mu\text{m}$ in diameter.
- Extend entire length of the muscle fiber.
- Muscle fibers of $50\ \mu\text{m}$ have 1,000 to 2,000 or more myofibrils
- Myofilaments are thick and thin filaments of the myofibril
- Thick and thin filaments lay parallel and are responsible for the striated appearance or banding
- Light band is I band, which is isotropic or singly refractive
- Dark band is A band, which is anisotropic or doubly refractive



Organelles of Skeletal Muscle



Organelles of Skeletal Muscle



- Mitochondria

- *Oblong shape organelles*
- *Located in the sarcoplasm*
- *Powerhouse of cell*
- *Contains enzymes for oxidative metabolism*

- Lysosomes

- *Capable of digesting the cell and its contents*



Organelles of Skeletal Muscle



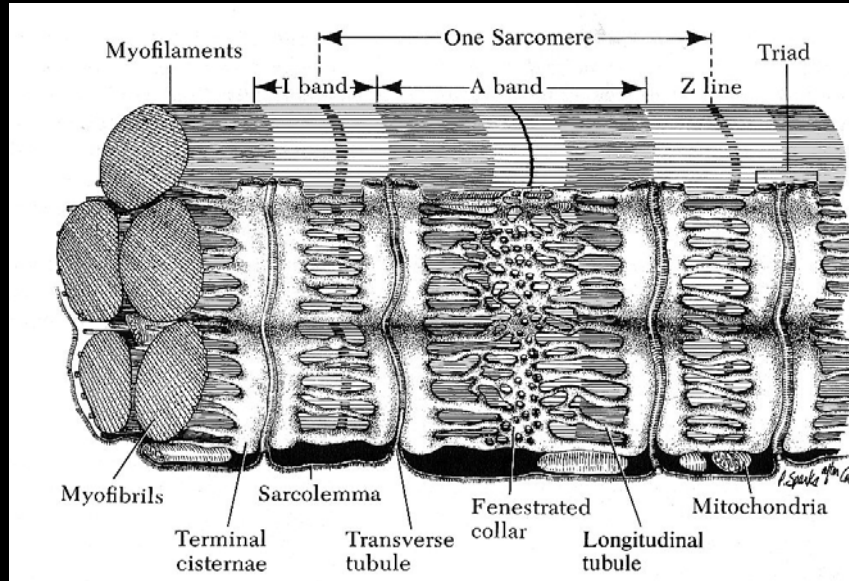
- Sarcoplasmic Reticulum

- *Endoplasmic reticulum of other cells*
- *Membranous system of tubules and reservoirs for calcium storage (cisternae)*
 - *Longitudinal tubules*
 - *Fenestrated collar*
 - *Terminal cisternae*

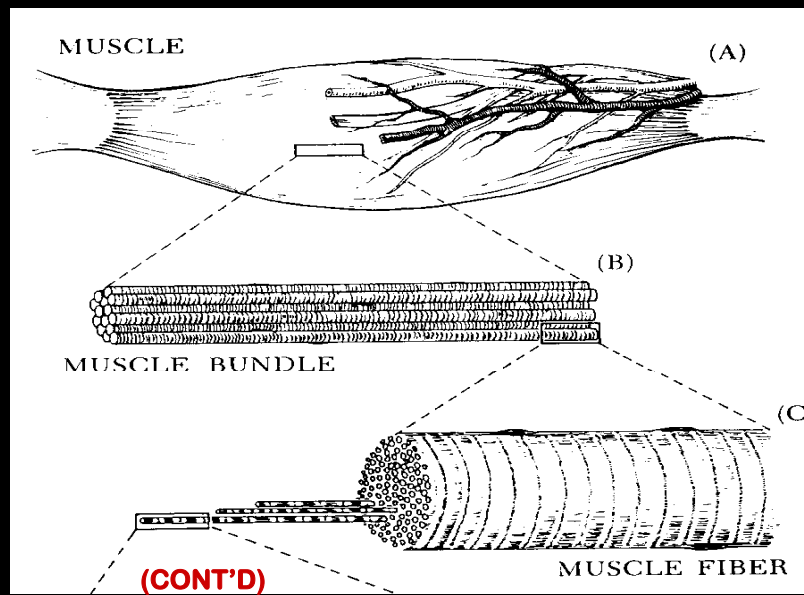
- T Tubules

- *T tubules run across the sarcomere at the A and I junction between the two tubular elements of the terminal cisternae*
 - *Carry nerve signal into muscle*
 - *Responsible for the release of Ca and ultimate contraction of sarcomeres*

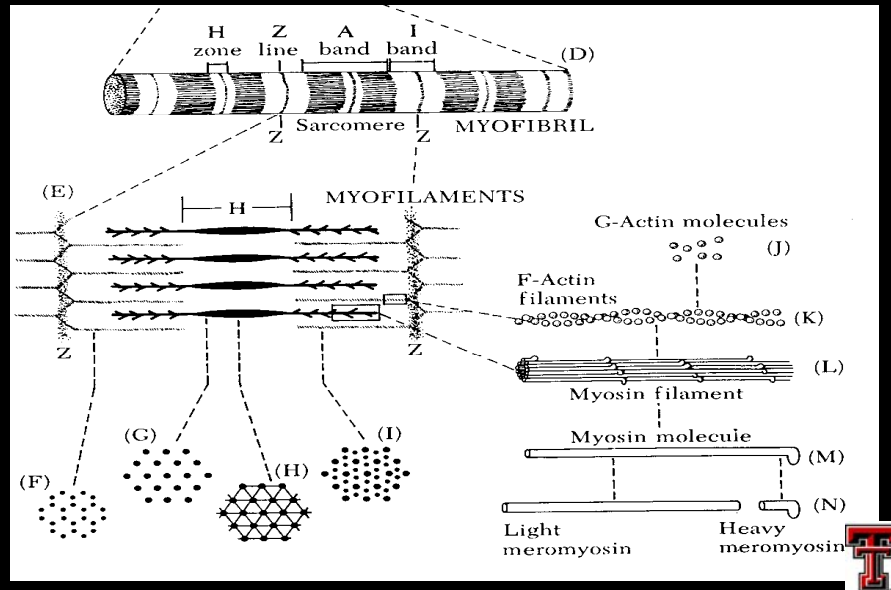
Organelles of Skeletal Muscle



Structure of Muscle



Structure of Muscle



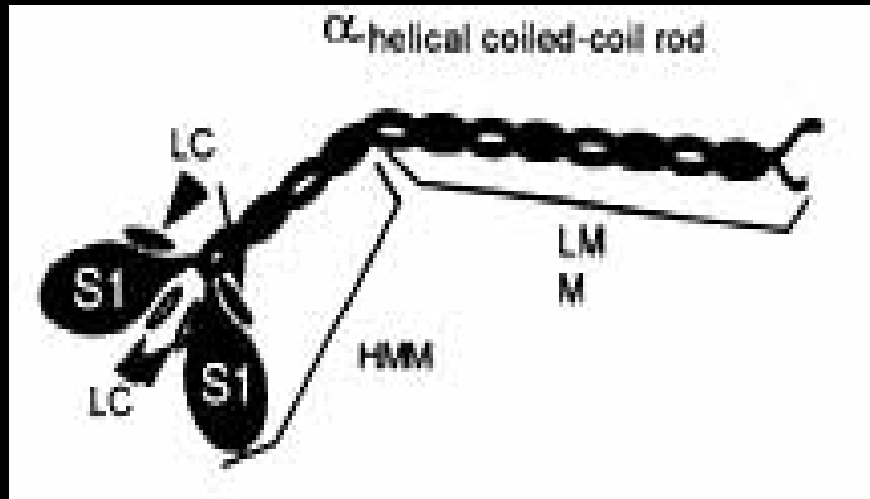
Structure of Muscle – Contractile proteins



- Myosin – rich in basic and acidic amino acids
 - Elongated rod shape with a thickened portion at one end.
 - Head region consist of heavy meromyosin
 - Tail region consist of light meromyosin
 - Large protein made up of two identical heavy chains and four light chains
 - α -helical coiled coil
 - Several hundred myosin molecules are arranged within each thick filament
 - MW=500,000



Structure of Muscle- Contractile Proteins

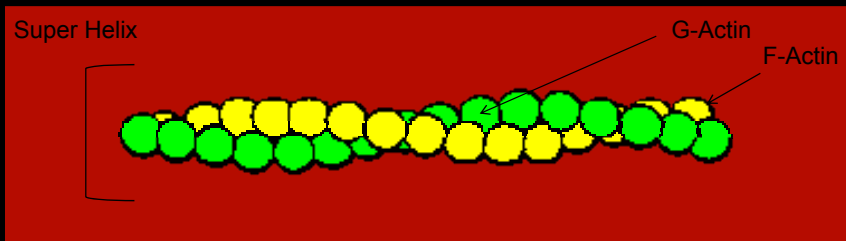


Structure of Muscle – Contractile proteins

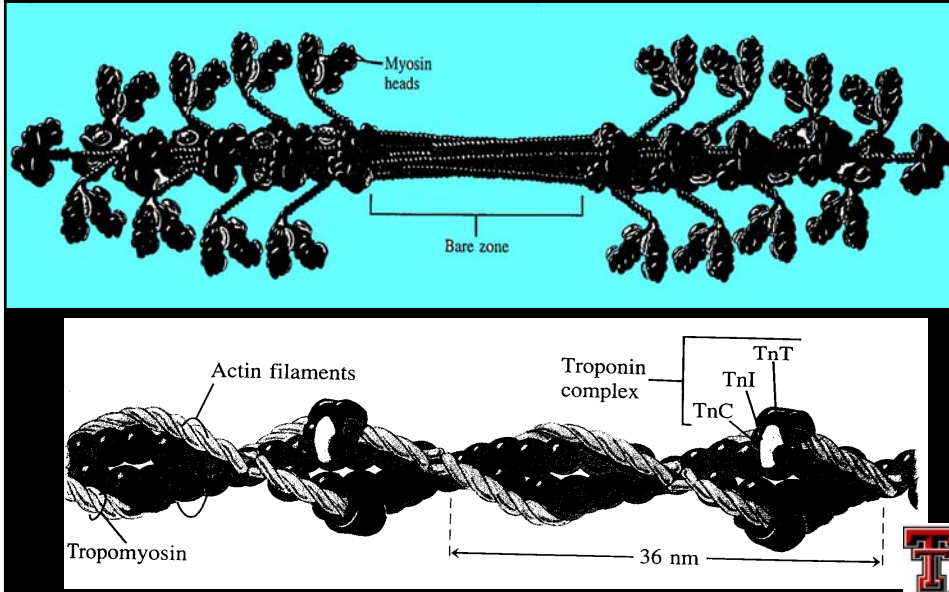


• Actin – rich in proline contributes to peptide chain folding and globular shape

- *G – actin = globular actin, single molecular form of actin*
- *Linking of G-actin forms F-actin*
- *Two strands of F-actin are spirally coiled around one another to form a super helix*
- *MW=42,000*



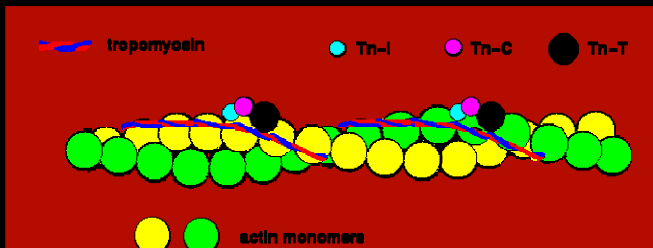
Structure of Muscle – Contractile proteins



Structure of Muscle – Regulatory proteins



- Troponin – found in actin (MW=18,000)
 - One molecule for every 7-8 G-actins
 - Pellet shaped – I, C, T
 - TN-I inhibits the actin-myosin interaction
 - TN-T binds tropomyosin
 - TN-C binds Ca ions
 - The calcium ion receptive protein for actomyosin-tropomyosin complex

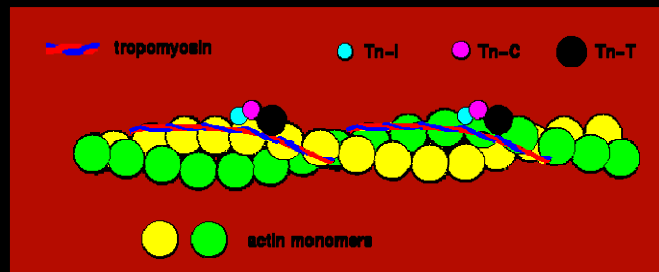


Structure of Muscle – Regulatory proteins

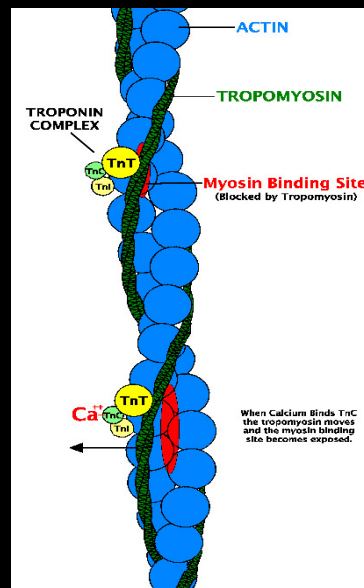


• Tropomyosin – found in actin (MW=64,000)

- One molecule extends the length of 7 G-actins
- One molecule lies on the surface of the 2 coiled F-actins
- Moves troponin T off the actin binding site in contraction



Structure of Muscle – Regulatory proteins



Structure of Muscle – Regulatory proteins



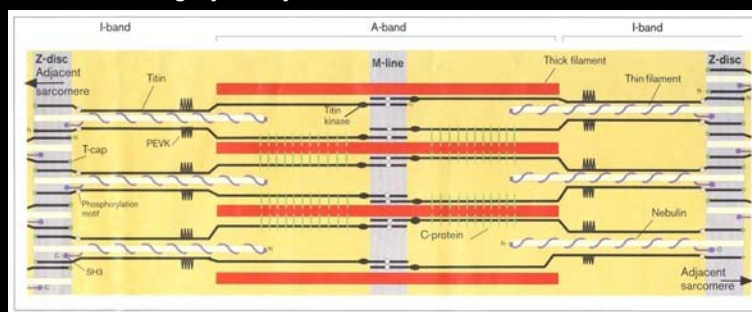
- β -actinin
 - Present in thin filament
 - Located at ends of actin filaments
 - Regulates length of actin by maintaining a constant length of $1\mu\text{m}$ in each one-half sarcomere
- α -actinin (MW = 206,000)
 - Component of Z line
 - Anchors actin filaments to the z line



Structure of Muscle – Cytoskeleton/Structural proteins



- M protein (MW = 170,000)
 - component of M line
- C protein (MW = 140,000)
 - 7 bands encircle each thick filament on both sides of H zone to maintain integrity of myosin filament



Structure of Muscle – Cytoskeleton/Structural proteins



- **Titin** (MW=2,800,000)

- *present between A and I bands*
- *largest single chain protein*
- *one molecule spans ½ of the sarcomere*
- *prevents over and under contraction of myosin*

- **Nebulin** (MW = 600,000)

- *is actin's "ruler" by regulating the length of actin*

- **Desmin** (MW = 55,000)

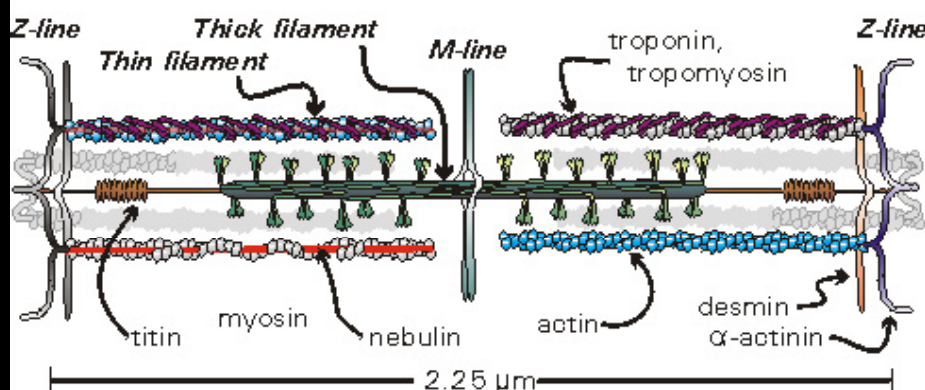
- *located along Z line, connects myofibrils to sarcolemma*



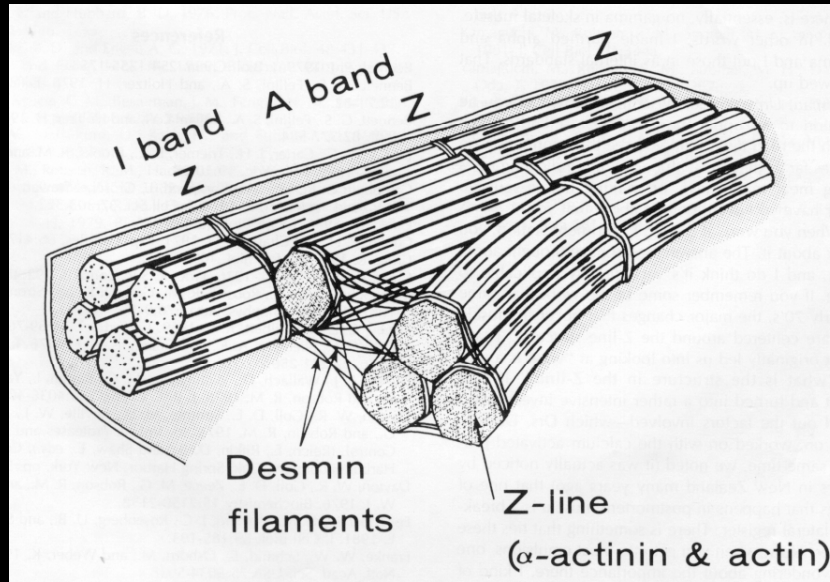
Structure of Muscle



A muscle sarcomere



Structure of Muscle



Structure of Muscle



Table 22-2. Proteins of the Myofibril

Protein	Molecular Weight	Subunits	Location	% Myo-fibrillar Protein
Contractile				
Myosin	520,000	2 of 220Kd ¹ , 4 of 20Kd	Thick filaments	43
Actin	42,000		Thin filaments	22
Tropomyosin	68,000	2 of 34Kd	Thin filaments	5
Troponin	69,000	30Kd, 21Kd, 18Kd	Thin filaments	5
Structural				
Titin	2,800,000		Full sarcomere	8
Nebulin	600,000		Thin filaments	3
C protein	140,000		Thick filaments	2
α -actinin	200,000	2 of 100Kd	Z lines	2
M protein	160,000		M lines	2
Desmin	55,000		Z lines	<1

¹Kilodalton = 1,000 daltons. One dalton is a unit of mass very nearly equal to that of a hydrogen atom.





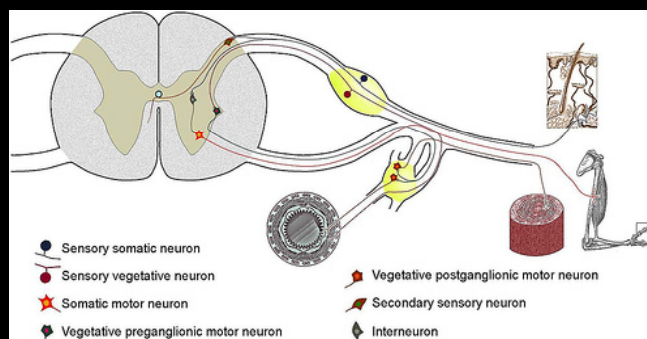
Muscle Contraction



Contraction



- Initiation in the central nervous system
- Motor neuron is activated and an action potential passes from spinal cord



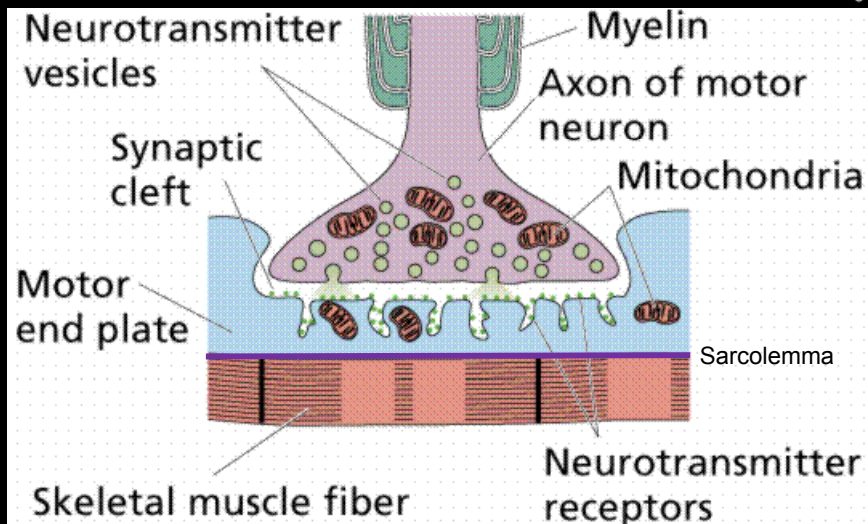
Contraction



- Action potential is conveyed to motor end plate of the affected muscle fibers
- Triggers the release of acetylcholine into the synaptic clefts on the muscle fiber surface
- Electrical resting potential under the motor end plate changes



Contraction



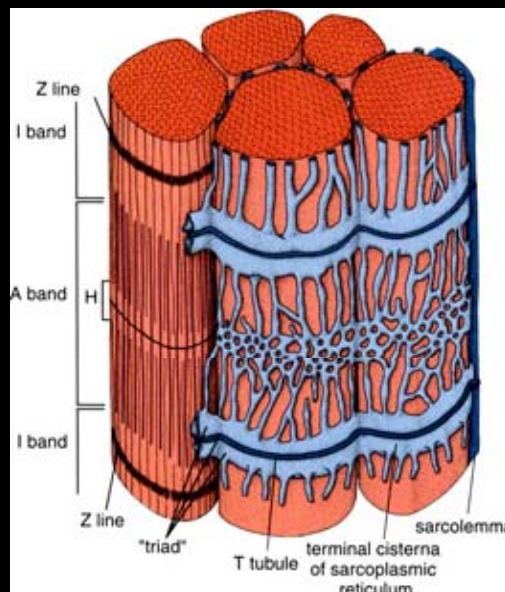
Contraction



- An action potential passes along the sarcolemma
- The action potential spreads inside the muscle fiber via the transverse tubules
- Where transverse tubules touch the sarcoplasmic reticulum, the terminal cisternae are depolarized and release calcium ions

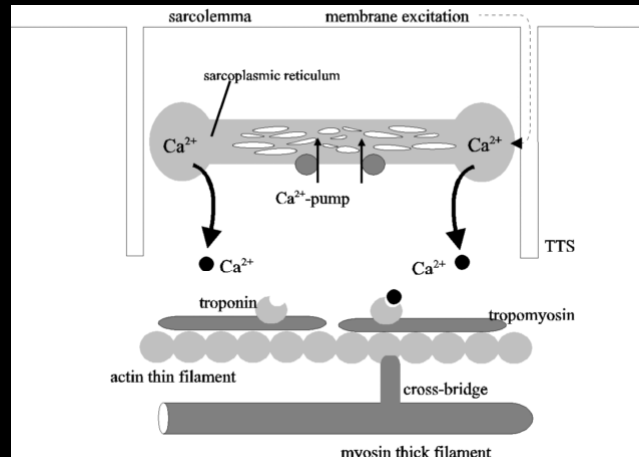


Contraction



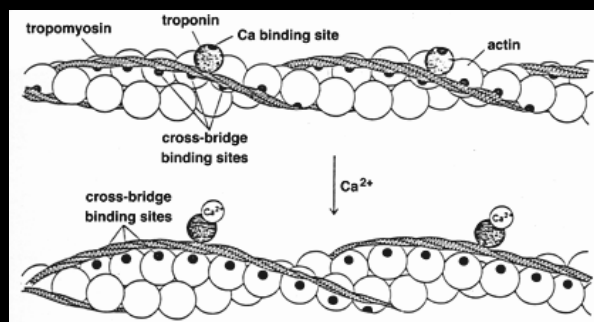
Contraction

- Calcium ions bind to troponin



Contraction

- Troponin moves tropomyosin from its blocking position close to the outside of the F-actin to a deeper position in the groove between the two actin chains that are wound together



Contraction

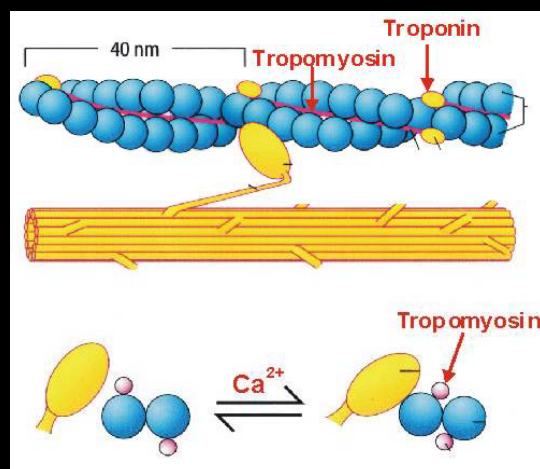
- The myosin heads attaches to actin
- Contact with actin causes myosin head to swivel and pull the thin filament



E Cross-bridge pulls actin filament (power stroke), ADP and **P** released from myosin

Contraction

- Myosin heads become detached, swivel, and reattach farther along the F-actin



Contraction



- The swiveling or rowing action enables the myosin heads to work their way along the F-actin and causes the sarcomere to shorten

• http://www.sci.sdsu.edu/movies/actin_myosin.html



Relaxation



- Nerve impulses stop and action potential ceases
- Acetylcholinesterase breaks down acetylcholine at the neuromuscular junction
- Flow of action potential along into the muscle fiber is terminated
- The terminal cisternae cease to release calcium ions



Relaxation

- The calcium pump in the membrane transports the calcium back into the sarcoplasmic reticulum
- Calcium ceases to bind to troponin
- Troponin returns to its blocking position
- Myosin heads are blocked from making changed attachments to actin and contraction ceases
- External forces returns muscle to original length

