Muscle Tissue

Muscle Tissue Outline

- General Functions of Muscle Tissue
- Characteristics of Muscle Tissue
- Classification of Muscle Tissue
- Skeletal Muscle Structure and Function
- Muscle Energetics
- Muscle Mechanics
- Types of Skeletal Muscle
- Cardiac & Smooth Muscle

General Function of Muscle Tissue

1. Movement
   1. Skeletal movements
   2. Control entrance and exits
   3. Movement of substances within the body
2. Postural maintenance
3. Thermogenesis
4. Support & Protection

Characteristics of Muscle Tissue

Differ from function!

1. Excitability
2. Conductivity
3. Contractility
4. Elasticity
5. Extensibility

Classification of Muscle Tissue

Classified on the basis of:
- shape of cells
- nucleus
- control
- presence/absence of striations

Gives us:
1. skeletal muscle
2. cardiac muscle
3. smooth muscle

Classification of Muscle Tissue

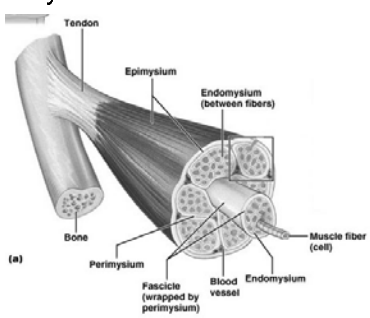
Muscle Tissue	Cell Shape	Striae	Nucleus	Control	Special structures
Skeletal	Cylindrical	Yes	Multi-nucleate & peripheral	Voluntary	none
Cardiac	Cylindrical & branched	Yes	Uninucleate & central	Involuntary	Intercalated discs
Smooth	Fusiform	No	Uninucleate & central	Involuntary	May be single-unit or multi-unit

Classification of Muscle Tissue

- Features shared among all muscle types
  - Contractile filaments (myofilaments)
  - Muscle cells are termed muscle fibers
  - Plasma membrane is called the sarcolemma
  - Cytoplasm is called sarcoplasm

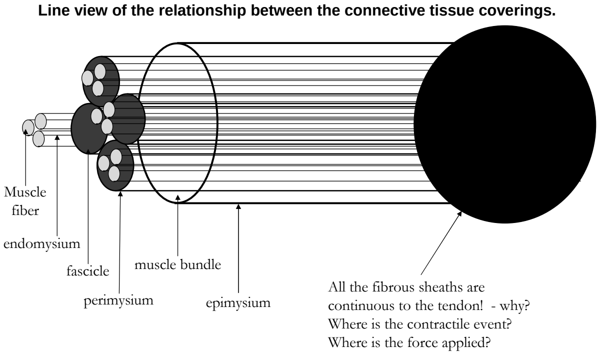
Skeletal Muscle Structure & Function

Gross Anatomy of Skeletal Muscle



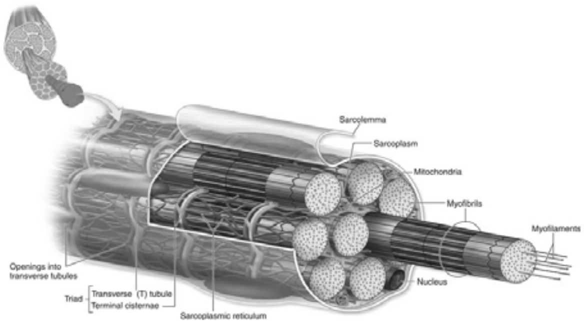
Skeletal Muscle Structure & Function

Line view of the relationship between the connective tissue coverings.



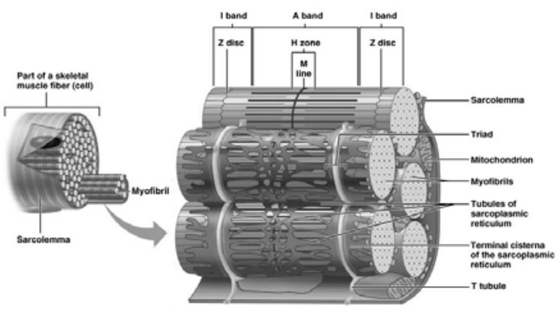
Skeletal Muscle Structure & Function

Microscopic Anatomy of Skeletal Muscle



Skeletal Muscle Structure & Function

Microscopic Anatomy of Skeletal Muscle



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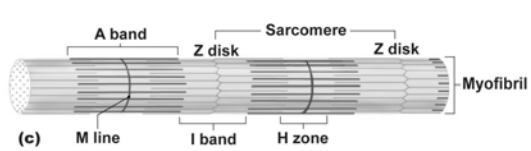
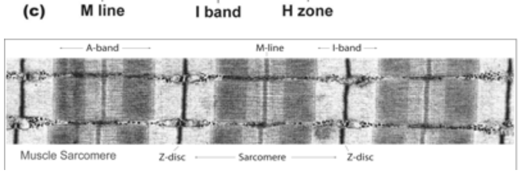
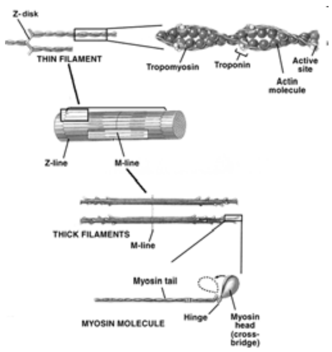
Microscopic Anatomy of Skeletal Muscle





Skeletal Muscle Structure & Function
Microscopic Anatomy of Skeletal Muscle



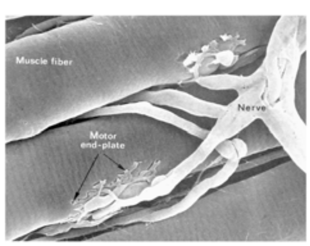
Skeletal Muscle Structure & Function
Physiology of Skeletal Muscle Action

- How do we get a muscle to shorten?
  - 1. Stimulate it
    - **Neuromuscular Junction Events**
  - 2. Get the filaments to attach to each other
    - **Excitation Contraction Coupling Events**
  - 3. Create a “bending” in one of the filaments to pull the other
    - **Sliding Filament Theory**
  - 4. Disconnect the filaments
    - **Relaxation**

Skeletal Muscle Structure & Function
Physiology of Skeletal Muscle Action

Neuromuscular Junction Events

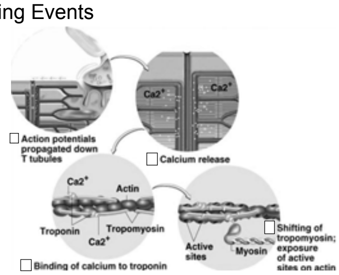
1. Action potential arrives at axon terminal
2. Acetylcholine (ACh) a neurotransmitter released from axon terminal via exocytosis
3. ACh binds to receptors on motor end plate of sarcolemma



Skeletal Muscle Structure & Function
Physiology of Skeletal Muscle Action

Excitation Contraction Coupling Events

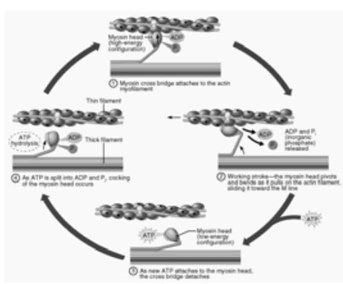
1. Ligand gated channels (ACh receptors) open allowing influx of sodium (Na^+)
2. Muscle action potential is created and travels across sarcolemma and down t-tubules
3. T-tubule depolarization causes Ca^{2+} release from sarcoplasmic reticulum
4. Ca2+ binds to troponin
5. Troponin-tropomyosin complex shifts exposing myosin binding sites on actin
6. Myosin attaches to actin (coupled)



Skeletal Muscle Structure & Function
Physiology of Skeletal Muscle Action

Sliding Filament Theory

1. ADP & P_i are released from myosin cross bridge
2. Causes "power stroke" of myosin, pulling actin filaments towards the center of the sarcomere
3. A new ATP attaches to myosin, releasing it from actin
4. ATP is hydrolyzed into ADP and Pi, "energizing" myosin
5. As soon as a binding site for myosin on actin is open myosin binds to actin and the process starts over



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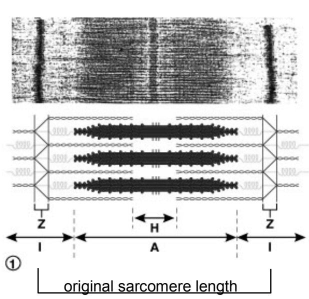

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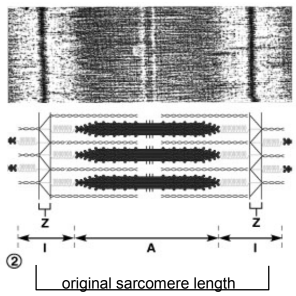
Physiology of Skeletal Muscle Action



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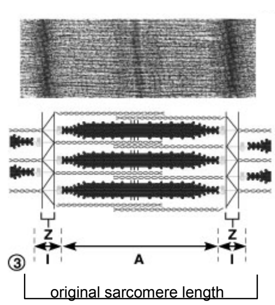
Physiology of Skeletal Muscle Action



Skeletal Muscle Structure & Function
Physiology of Skeletal Muscle Action

Relaxation

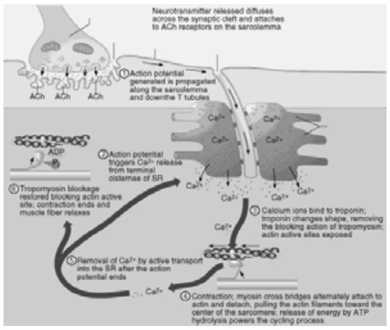
1. ATP is required to detach myosin from actin
2. Ca^{2+} is removed by active transport back into the sarcoplasmic reticulum – requiring additional ATP
3. troponin-tropomyosin complex covers the binding site, preventing further cross-bridge cycling (sliding filament operations).

Skeletal Muscle Structure & Function

Physiology of Skeletal Muscle Contraction

- Overview of process

animation link



Muscle Energetics

Two important questions:

1. What is cellular energy used for in muscle action?
   a. Maintenance of cell membrane potential
   b. Active transport of Ca2+ into SR
   c. Removal of myosin from actin
2. Where does it come from?
   Depends…

Muscle Energetics

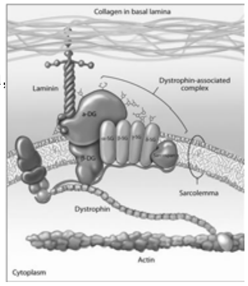
During rest:
fatty acids are metabolized
glucose is used, excess stored as glycogen

During moderate activity: (aerobic)
glycogen is broken down to glucose and is metabolized

During intense activity: (anaerobic)
glucose is broken down into pyruvate, then converted to lactic acid
Creatine phosphate donates P_i to ADP to make additional ATP

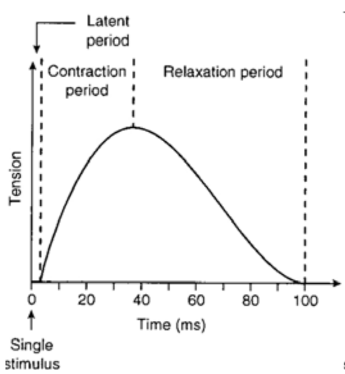
Muscle Mechanics

- Transmission of force from the sarcomere to the tissue at large
  - Sarcomeres linked by dystrophin to sarcolemma, then via a complex of membrane proteins interacting with cytoskeletal framework



Muscle Mechanics

The response of skeletal muscle to an action potential in a motor neuron is a **twitch.**



Muscle Mechanics

Single twitches may not generate enough force to "get the job done

What happens when resistance is greater than the force of contraction?

Isometric contraction

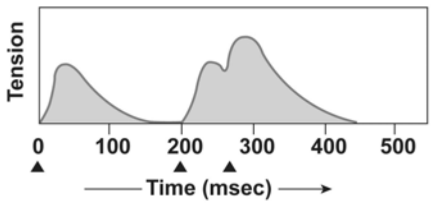
How then can a stronger contraction be created in muscle tissue?

1. Add the twitches together = summation
2. Increase the number of motor units = recruitment
3. Change the length-tension relationship of the muscle fibers
4. Increase size of muscle fibers or numbers of muscle fibers

Muscle Mechanics

1. Summation

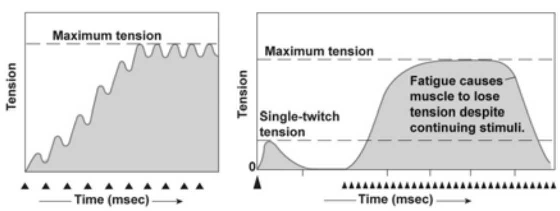
- Stimulation of the muscle fiber after the contraction period, but before complete relaxation
- Causes next twitch to add tension to the first twitch and so on…



Muscle Mechanics

Summation

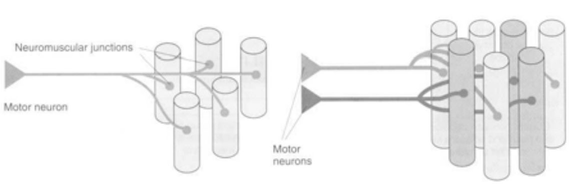
- Repeated stimuli can result in tetanus



Muscle Mechanics

2. Recruitment

- Increase the number of active motor units
  - Motor unit = motor neuron + all of the muscle fibers it innervates
- More motor units = more tension = more strength!



Muscle Mechanics

2. Recruitment

– Different muscles have different sizes of motor units

Ex. Larynx 3-4 muscle fibers per motor unit

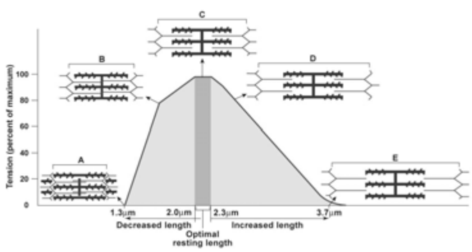
Gastrocnemius may have up thousands!

Good animation

Muscle Action

3. Length-Tension Relationship

- Correct length or stretch of the muscle fiber creates a more optimal overlap of the myofilaments
- More potential interaction between myofilaments = stronger contraction

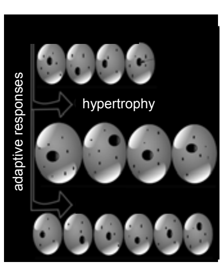


Muscle Mechanics

4. Increase size and or number of muscle fibers (adaptive responses)

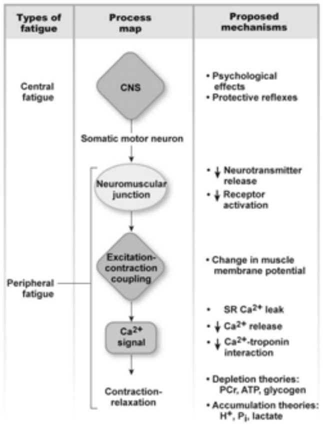
– Increase size
  - hypertrophy
– Increase number
  - Hyperplasia

– How does this happen?



Muscle Mechan

- Fatigue
  - Loss of strength in a muscle, may be due to?
  - May also be due to interference with the Neurotransmitters and receptors!



Mechanism	Antagonist	Preferred receptor	Clinical use
Ganglionic blocking agents	Hexamethonium	Ganglion type	none[1]
	Mecamylamine	Ganglion type	
	Trimethaphan	Ganglion type	Rarely used for blood pressure decrease during surgery[1]
	Atracurium	Muscle type	muscle relaxant in anaesthesia[1]
	Doxacurium	Muscle type	
Non-depolarizing neuromuscular blocking agents	Mivacurium	Muscle type	
	Pancuronium	Muscle type	muscle relaxant in anaesthesia[1]
	Tubocurarine	Muscle type	Rarely used [1]
	Vecuronium	Muscle type	muscle relaxant in anaesthesia[1]
Depolarizing neuromuscular blocking agents	Succinylcholine	Muscle type	
Centrally acting nicotinic antagonists	18-Methoxycoronaridine	α3β4	

Types of Skeletal Muscle Fibers

- All skeletal muscle is skeletal muscle?
  - Yes but two basic are varieties
    - Oxidative & Glycolytic
      - ratio is dependent on genetics
      - Glycolytic muscles
        - » 3 types (Type IIa, IIb, IIx)
        - » Fast contraction action
        - » Generally paler in color due to lower amounts of myoglobin and vascularity
        - » utilize anaerobic pathways for energy
        - » not use for long term endurance activities
      - Oxidative
        - » Use aerobic processes
        - » Long term endurance activities
        - » Highly vascular, more myoglobin

Types of Skeletal Muscle Fiber

Fiber Type	Type I fibers	Type II a fibers	Type II x fibers	Type II b fibers
contraction time	slow	moderately fast	fast	very fast
size of motor neuron	small	medium	large	very large
resistance to fatigue	high	fairly high	intermediate	low
activity used for	aerobic	long-term anaerobic	short-term anaerobic	short-term anaerobic
maximum duration of use	hours	<30 minutes	<5 minutes	<1 minute
power produced	low	medium	high	very high
mitochondrial density	high	high	medium	low
capillary density	high	intermediate	low	low
oxidative capacity	high	high	intermediate	low
glycolytic capacity	low	high	high	high
major storage fuel	Triglycerides	CP, glycogen	CP, glycogen	CP, glycogen

Comparison of Oxidative & Glycolytic Muscle Fibers