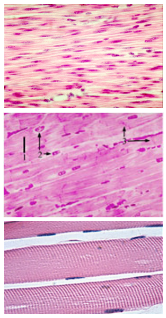
Muscle Structure

Chapter 1

Muscle Structure:
Classification

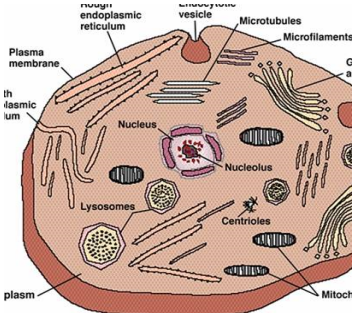
- Smooth
  - Autonomous system
  - Spindle shaped
  - Uninucleated
- Striated
  - Cardiac
    - Autonomous system
    - Uninucleated
    - Cylindrical
  - Skeletal
    - Voluntary control
    - Cylindrical
    - Multinucleated
    - Striated



Muscle Structure

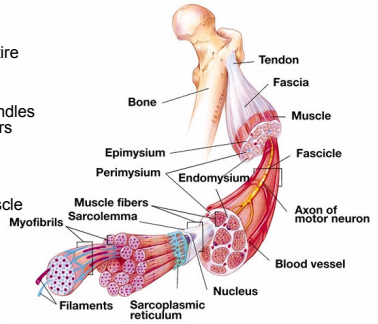
- Human body contains over 400 skeletal muscles
  - 40-50% of total body weight
- Characteristics
  - Irritability
    - Ability to respond to a stimulus
  - Contractility
    - Ability to shorten
  - Extensibility
    - Ability to lengthen
  - Elasticity
    - Ability to return to resting length

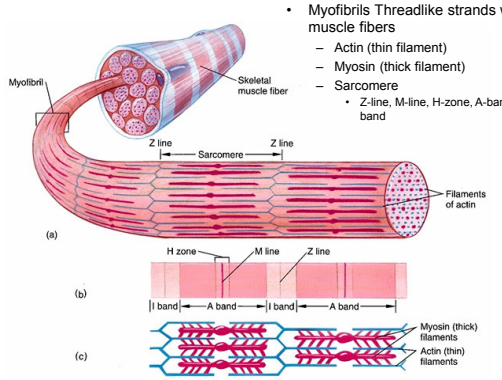
Structures in a typical cell



Gross Structure of Muscle

- Epimysium
  - Surrounds entire muscle
- Perimysium
  - Surrounds bundles of muscle fibers
    - Fascicles
- Endomysium
  - Surrounds individual muscle fibers





- Sarcolemma: Muscle cell membrane
- Myofibrils Threadlike strands within muscle fibers
  - Actin (thin filament)
  - Myosin (thick filament)
  - Sarcomere
    - Z-line, M-line, H-zone, A-band & I-band

- Elastic tissue (proteins) within the sarcomere.
  - Titan: extends from the Z-disc to the M-line.
  - Elastic in PEVK region
    - amino acids: proline, glutamate, valine, and lysine
  - Type II fibers have more titan than Type I.
- Connective tissue related to fatigue?
  - Weight bearing vs. non-weight bearing.
  - "hitting the wall"

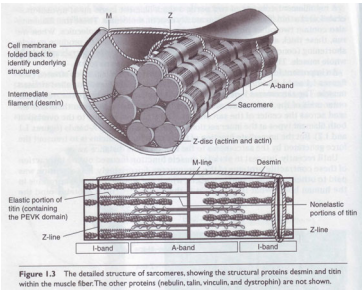
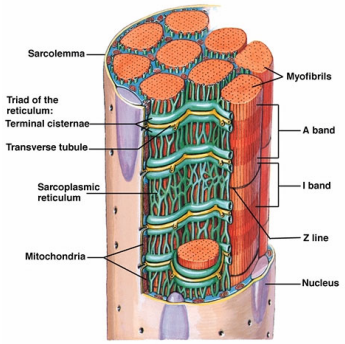


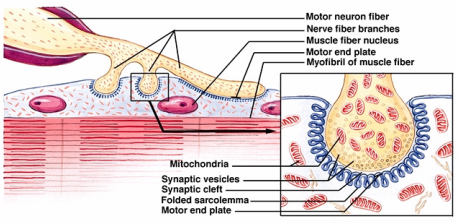
Figure 1.3 The detailed structure of sarcomeres, showing the structural proteins desmin and titin within the muscle fiber. The other proteins (nebulin, talin, vinculin, and dystrophin) are not shown.

- Within the sarcoplasm
  - Sarcoplasmic reticulum
    - Storage sites for calcium
  - Transverse tubules
  - Terminal cisternae
  - Mitochondria



Neuromuscular Junction

- Where motor neuron meets the muscle fiber
- Motor end plate: pocket formed around motor neuron by sarcolemma
- Neuromuscular cleft: short gap
- Ach is released from the motor neuron
  - Causes an end-plate potential (EPP)
    - Depolarization of muscle fiber



Muscle Structure
Key components in the muscle cell

- Mitochondria
  - Within muscle cell (in cytoplasm)
  - Main function: Produce energy ("powerhouse")
  - Location of oxidative conversion of foodstuffs into useable cellular energy
  - *Limiting factor in running endurance performance?*

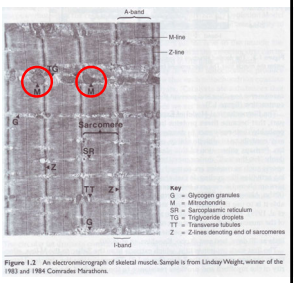


Figure 1.2 An electronmicrograph of skeletal muscle. Sample is from Lindsay Weight, winner of the 1983 and 1984 Comrades Marathons.

Muscle Structure
Key components in the muscle cell

- Fat Droplets
  - Fats generally stored in fat cells
  - …but, can be stored in muscle cell as triglyceride molecules
    - Three molecules of fatty acids and one molecule of glycerol
  - Source of energy
    - lipolysis; enzyme: lipase

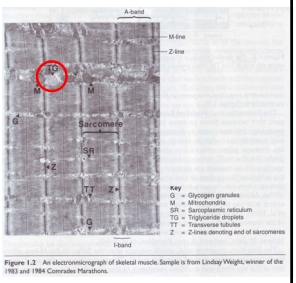


Figure 1.2 An electronmicrograph of skeletal muscle. Sample is from Lindsay Weight, winner of the 1983 and 1984 Comrades Marathons.

Muscle Structure
Key components in the muscle cell

- Glycogen
  - Polysaccharide (i.e., animal starch)
    - Lots of glucose molecules
  - Glycogenolysis: Breakdown of glycogen to glucose
  - Glyconeogenesis: Formation of glycogen from noncarbohydrate sources
  - Glycogenesis: Formation of glycogen from carbohydrate sources
  - Glycogen stored in muscles and liver
  - Total glycogen storage is relatively small and can be depleted in a few hours of exercise

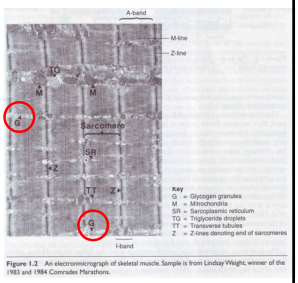
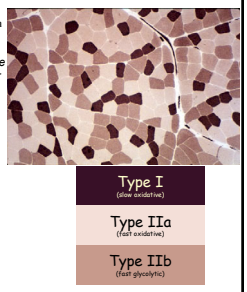


Figure 1.2 An electronmicrograph of skeletal muscle. Sample is from Lindsay Weight, winner of the 1983 and 1984 Comrades Marathons.

Muscle Structure:
Fiber Type

- Slow-twitch (Type I)
  - Oxidative
  - High content of myoglobin
    - Myoglobin transfers O_2 carried in blood to mitochondria and act as a oxygen store in muscles
  - Slow contraction time vs. Type II
    - *…but contraction time for some athletes may be comparable to Type II contraction times of non-athletes.*
  - Fatigue resistant
- Fast-twitch (Type II)
  - *At least 5 subtypes (IIa, IIb, IIc, IIab, IIac)*
  - Type IIa
    - Oxidative-glycolytic
    - Intermediate – can be fatigue resistant
  - Type IIb
    - Glycolytic
    - High force production
    - Short duration
  - Type IIc
    - uncertain origin
    - Capable of being developed to I or IIa?
    - More power than IIb



Muscle Fiber Types

	Fast Fibers		Slow fibers
Characteristic	**Type IIb**	**Type IIa**	**Type I**
Number of mitochondria	Low	High/mod	High
Resistance to fatigue	Low	High/mod	High
Predominant energy system	Anaerobic	Combination	Aerobic
ATPase	Highest	High	Low
V_{max} (speed of shortening)	Highest	Intermediate	Low
Efficiency	Low	Moderate	High
Specific tension	High	High	Moderate

Summary Muscle Structure

- Muscle Structure
  - Gross to cell level

  - Classification
  - Characteristics
  - Muscle structures
  - Connective tissue
  - Key components in a muscle cell
  - Muscle fiber type

Muscle Function

- Primary functions related to human movement:
  - Produce Movement
  - Maintain Posture
  - Stabilize Joints

  } Generate Force
- Other functions:
  - Protection
  - Regulation of body temperature
  - …

Muscle Contraction

- CNS signal
- Transmission of signal to motor end plate via α motor neurons.
- Upon reaching post-synaptic membrane threshold, signal is transmitted throughout muscle fibers of a motor unit (α motor neuron and all innervated muscle fibers).

Muscular Contraction

- The sliding filament model
  - Muscle shortening occurs due to the movement of the actin filament over the myosin filament
  - Formation of cross-bridges between actin and myosin filaments “Power stroke”
  - Reduction in the distance between Z-lines of the sarcomere

The Sliding Filament Model

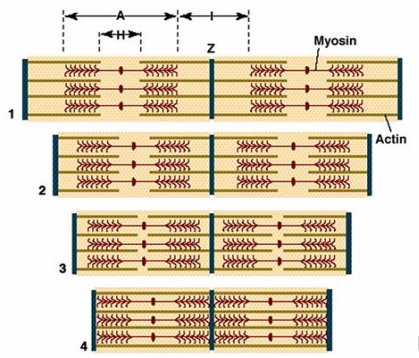


Fig 8.5

Actin & Myosin Relationship

- Actin
  - Actin-binding site
  - Troponin with calcium binding site
  - Tropomyosin
- Myosin
  - Myosin head
  - Myosin tails

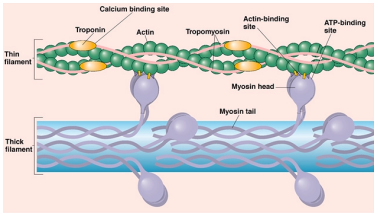


Fig 8.6

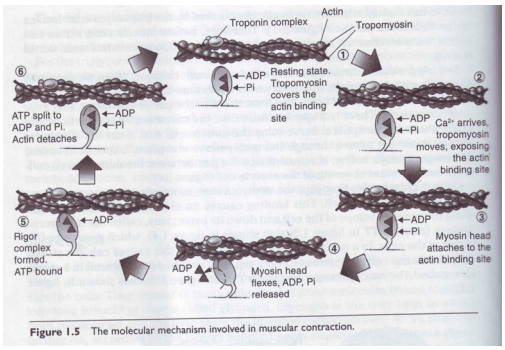


Figure 1.5 The molecular mechanism involved in muscular contraction.

Is the myosin binding to actin firm or a series of loose couplings (Figure 1.6, p11)?

Energy for Muscle Contraction

- Adenosine Triphosphate (ATP) is required for muscle contraction
  - Myosin ATPase breaks down ATP as fiber contracts
- Sources of ATP
  - Phosphocreatine (PC)
  - Glycolysis
  - Oxidative phosphorylation

Muscle Function:
Role of Muscle

- Agonist: (prime mover) functions to cause a movement
- Antagonist: functions to resist movement
- Stabilizer: functions to fixate an area so another movement can occur
- Synergist: assist another muscle
- Neutralizer: functions to prevent undesired movement

Muscle Function:
Muscle Action

- Isometric: No change in muscle length
- Isotonic: Change in length (same external weight)
  - Concentric
    - muscle length shortens during contraction
  - Eccentric
    - muscle length increases during contraction
- Isokinetic: Angular speed is constant during contraction
  - Concentric
  - Eccentric

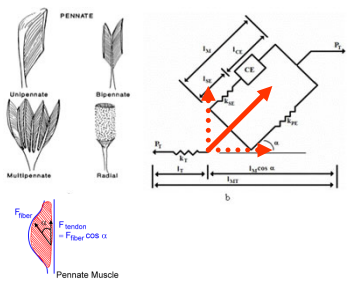
Summary Muscle Function

- Sliding filament theory
- Role of muscle
- Muscle action

Muscle Performance

- How well muscle functions are carried out.
  - i.e., ability to generate force
- Factors that influence muscle performance:
  - Angle of attachment
  - Length-tension relationship
  - Force-velocity relationship
  - *Fatigue*

Muscle Performance:
Angle of Attachment and Pennation



- Length-Tension Relationship of Muscle Contraction
  - The amount of force generated by a muscle is dependent on length of muscle.
  - Muscles that cross two joints
    - concurrent movements at both joints not maximized

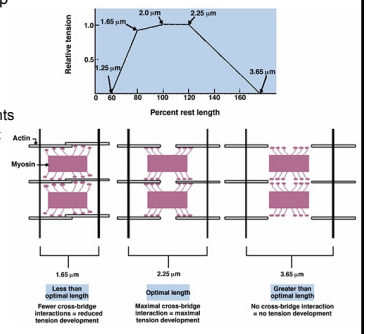
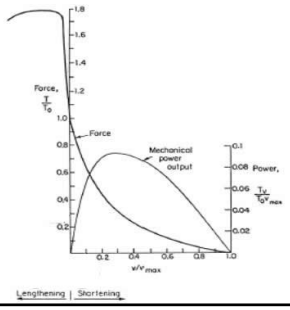


Fig 8.17

Muscle Performance:
Force – Velocity Relationship

The amount of force generated by muscle is dependent on the velocity of contraction.



Muscle Performance
Fiber Type

- Force
- Contraction velocity
- Power
  - Force x Velocity
  - Rate of transformation of chemical to mechanical energy
- Fatigue resistance

Fiber Type Composition Sprinters vs. Endurance Athletes

Type of Athlete	Type I Muscle Fibers (%)
Sprinters	26
Sprinters and Jumpers	37-39
Weight lifters	44-49
Cyclists and swimmers	50
Middle-distance runners	45-52
Elite half-marathon runners	54
Canoeist	60
Elite rowers	60-90
Elite distance runners	79-88
Cross-country skiers	72-79

Fiber Type Composition Sprinters vs. Endurance Athletes

Different physiological and physical requirements of sprinters and distance runners

Attribute	Sprinter	Distance Runner
Size	Large (>80kg)	Small (<50kg)
Explosive Power	Very high	High
Aerobic capacity	Unimportant	Important
Fatigue resistance	Unimportant	Crucial
Muscularity	Essential	Disadvantage
Body type	Mesomorphic	Ectomorphic
Muscle fiber compositions	80% Type II	60% Type I

Training

- Purpose: Minimize fatigue
  - General tiredness (Taber's)
  - Reduction of force generating capability of muscle
- Develop muscle fiber types by training at different intensities.
- Muscle recruitment based upon:
  - Physiological model
    - related to intensity of exercise
      - Long slow distance: Type I
      - High intensity: Type II
  - Integrated Neuromuscular Recruitment Model
    - Muscles are recruited based upon information received by the CNS
      - Cardiostat: control based upon O_2 supply to the heart or brain
      - Glycostat: control based upon blood glucose (protect brain?)
      - Thermostat: control based upon heat accumulation
    - *Protect the body from harming itself*
  - Central fatigue
    - Neurotransmitters within brain change signals being sent to muscles.
  - Is muscle recruitment influenced by a perception of how much more work can be done?

"Only the fast and strong die young"

- Endurance athletes tend to outlive sprinters.
  - Health benefits from endurance exercise?
  - Related to muscle fiber type?
    - Fiber type influences chosen level of physical activity?
    - People with more Type II muscle fibers may be more prone to developing hypertension, diabetes and obesity (Bassett, 1994).
    - People with more Type I fibers have greater levels of blood HDL-cholesterol (Tikkeanen et al., 1991).

Summary

- Muscle Performance
  - Length tension
  - Force velocity
  - Angle of attachment
  - Fatigue
  - Training