Muscle Function:
Understanding the Unique Characteristics of Muscle

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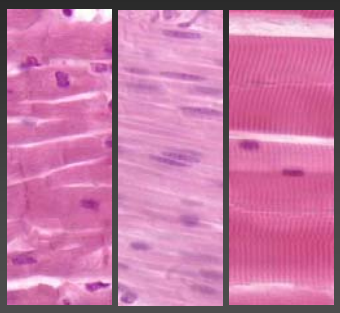
KIN 856 – Physical Bases of Coaching

Three types of muscle

- Cardiac muscle
  - Involuntary
- Smooth muscle
  - Involuntary
- Skeletal muscle
  - Voluntary
  - Involuntary



Muscle Structure

Muscle (Epimysium)

⇩

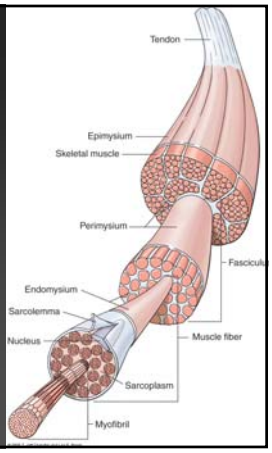
Muscle Fascicle (Perimysium)

⇩

Muscle Fiber (Endomysium)

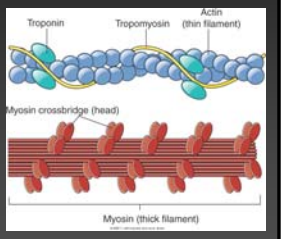
⇩

Myofibrils

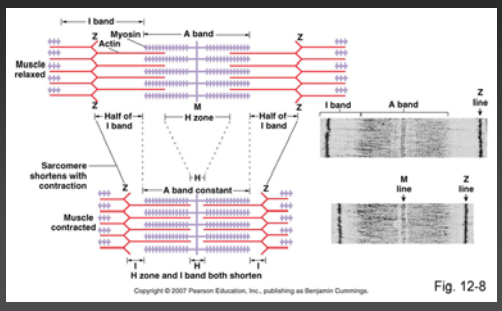


Myofibrils – actin and myosin

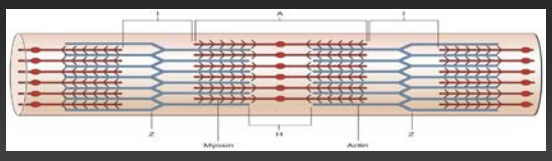
- **Myosin** – thick filament
  - Globular heads
- **Actin** – thin filament
- Myosin binds to actin form crossbridges
- Formation and breaking of crossbriges is what underlies muscle contraction



Looking closely at the myofibril

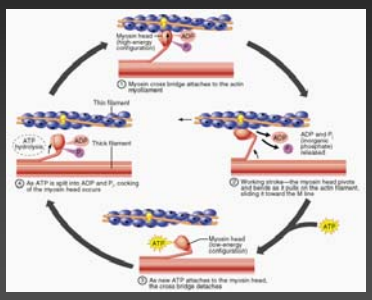


Actin, Myosin & Sarcomeres



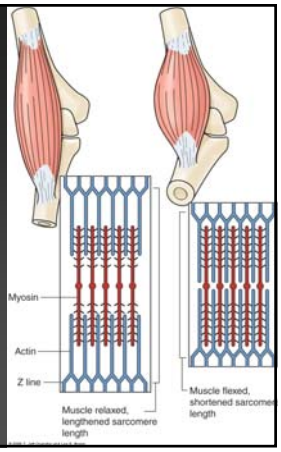
- A Band – all myosin, length of the thick filament
- I Band – only actin
- H Band – only myosin
- Z Disk/ line – actin attachment point
- M Line – myosin attachments (middle of H band)
- **Sarcomere – Basic unit of muscle**
  - **From Z-line to Z-line**

Sliding Filament Theory



Contraction

- Repeated cycling shortens each sarcomere
- As sarcomeres in series with one another shorten so does the muscle.



Sarcomere Force – Length Characteristics

- Every muscle and muscle fiber has an optimal length (~ 2.2 µm)
  - ✓ Where it can form the greatest number of crossbridges and thereby produce the most force.
- At shorter and longer lengths foce is compromised
  - ✓ Shorter – actin molecules overlap
  - ✓ Longer – myosin gets pulled from actin

Sarcomere Force – Length Characterstics

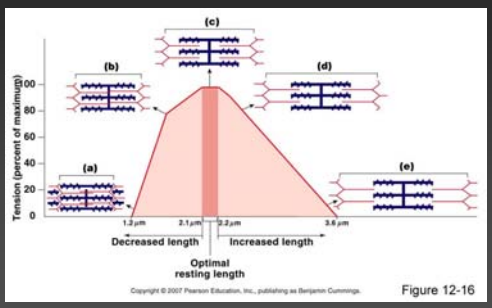
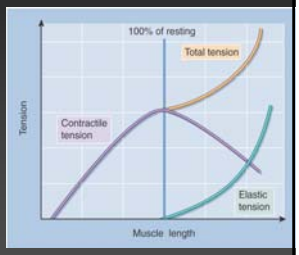


Figure 12-16

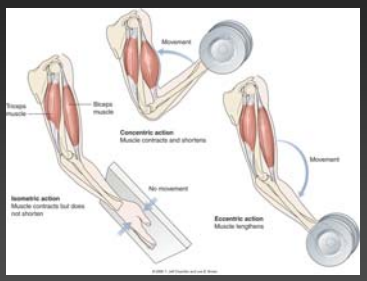
Muscle Force – Length Curve

Three things shown on this curve

1. **Active muscle force**
   - ✓ **Muscle contraction**
2. Passive force
   - ✓ Stretched connective tissue
3. Total force
   - ✓ Sum of both



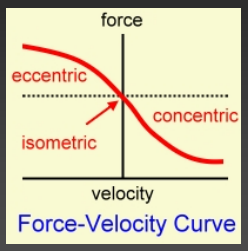
Types of muscle contraction



Isometric – constant length, velocity = 0
Concentric – shortening contraction
Eccentric – lengthening contraction

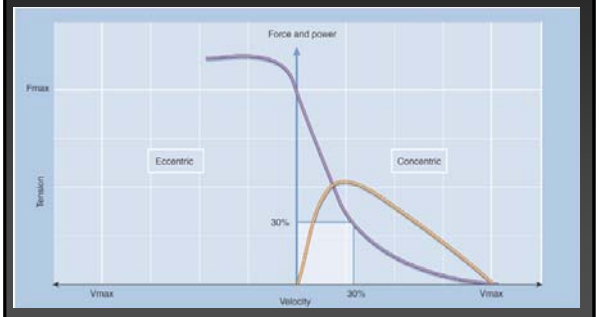
Muscle Force - Velocity Characteristics

- Force and velocity are inversely related
  - Fast contraction – low force
  - High force – slow contraction speed
- Greatest force during an isometric contraction – right?



Force-Velocity Curve

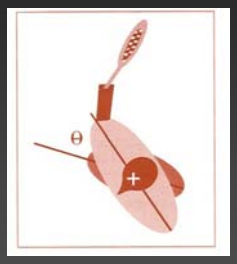
Muscle Force - Velocity Characteristics

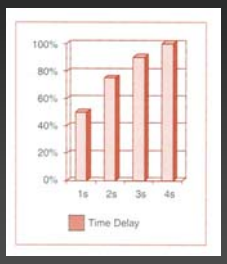


Elastic Energy Storage

- Muscles stretched while under tension will store energy
- Can be returned during an immediate concentric contraction
- Augment performance
  - Vertical jump
  - Baseball pitch
  - Tennis serve

Elastic Energy Storage: Use it or Lose it





Timing in Storage **Timing in Release**

All muscle fibers are not the same

- Different fiber types
  - Type I: Slow twitch – lower force, fatigue resistant
  - Type IIa: Fast twitch – higher force, fatigue resistant
  - Type IIb: Fast twitch – highest force, fatigue quickly

Muscle Fiber Type Characteristics

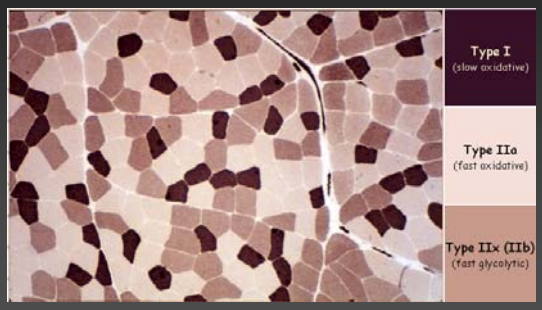
Comparison of Slow and Fast Twitch Fibers

	Type I (slow-oxidative)	Type IIa (fast-oxidative)	Type IIb (fast-glycolytic)
Use (examples)	Posture	Walking	Sprinting
Motor unit size	100+ fibers	2-6 fibers	2-6 fibers
ATPase activity*	Low	High	High
Contraction speed	Slow	Fast	Fast
Fatigue resistance	High	Intermediate	Low
Myoglobin content	High	High	Low
Capillary density	High	Intermediate	Low
Fiber color	Red (dark)	Red	White
Glycolytic enzymes	Low	Intermediate	High
Mitochondrial content	Packed	Intermediate	Sparse

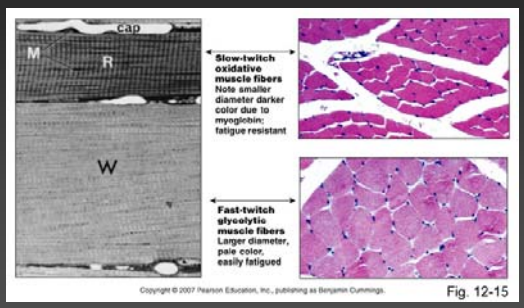
*Rapid breakdown of ATP

See also Table 12-2 in Silverthorn

Muscle Fiber Types

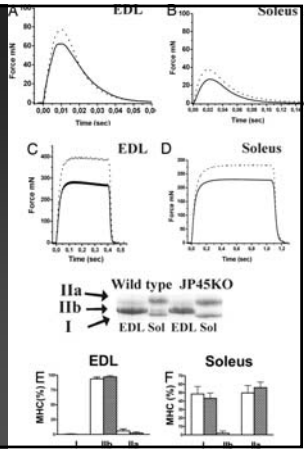


Muscle Fiber Types



Fiber Types

- EDL – extensor digitorum longus
  - All Type IIb
  - Higher twitch
  - Higher force
  - Earlier onset of fatigue
- Soleus
  - All Type I, IIa
  - Lower twitch
  - Fatigue resistant

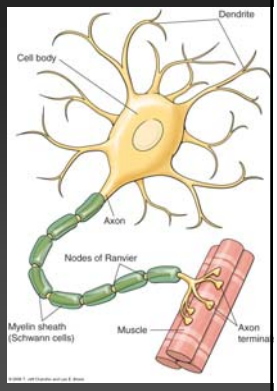


Fiber type and sport

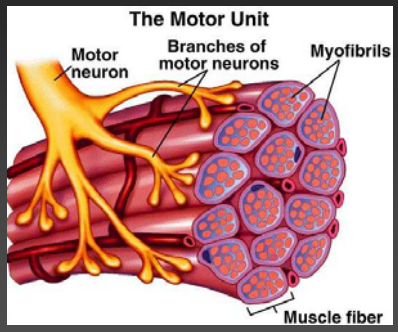
	Type IIa Oxidative	Type IIb Glycolytic
Marathoners	82%	18%
Distance swimmers	74	26
Couch potatoes	45	55
Sprinters	37	63

Motor unit

- Equal to a α-motor neuron and all the muscle fibers it innervates
- Myelin
  - ✓ Signal transmission
  - ✓ 'Coding' of movement patterns
- Neurotransmitter
  - ✓ Acetylcholine

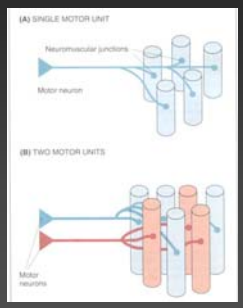


Motor Unit



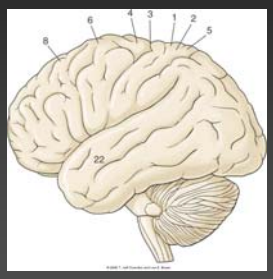
Muscles are made up of many motor units of different types

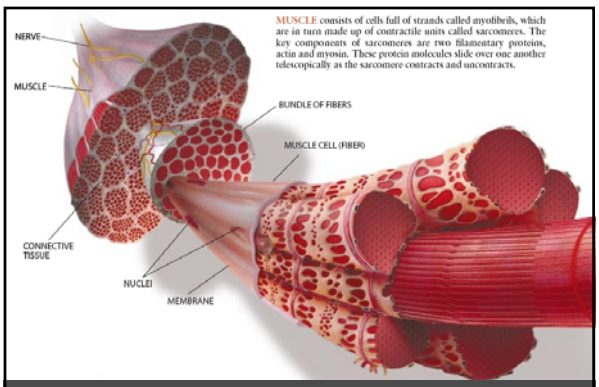
- Motor units are 'inter-twined'
- All muscle fibers in a motor unit are of the same fiber type (e.g. Type I)
- Motor units can include 1 – 100s of muscle fibers.



Motor Cortex

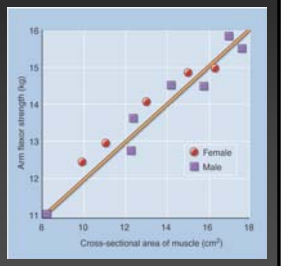
- Area 4 – motor cortex
  - Motor tracts
  - Pyramidal system
- 85% cross over to the contalateral side
  - R brain controls L side
- Motor cortex organized by movement
- Area 6 – Premotor cortex - planning





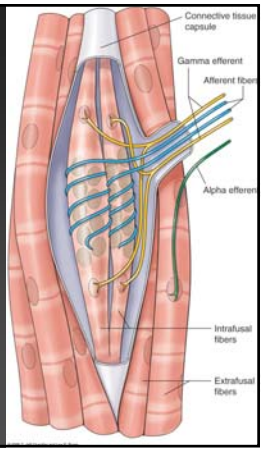
Muscle/ Fiber size and strength

- Greater the cross sectional area the greater the strength
- Regular strength training increases muscle x-sectional area
- Also related to function
  - ✓ Fine motor control - small
  - ✓ Strength -larger

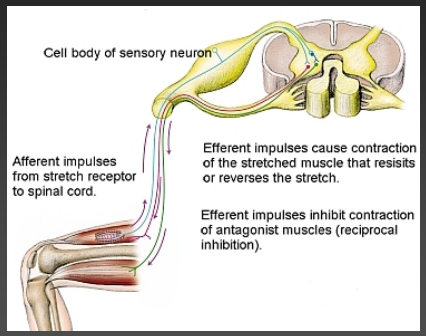


Muscle Spindles

- Intrafusal fibers
- In parallel with muscle fibers
- Proprioception - sense changes in length and contraction velocity
- Innervated by γ- motor neurons
  - ✓ Establish set point
  - ✓ Gauge stretch
  - ✓ Provide feedback to CNS
- Stretch reflex

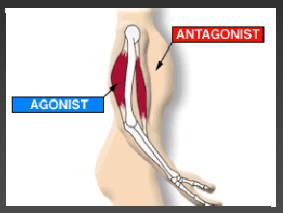


Stretch Reflex



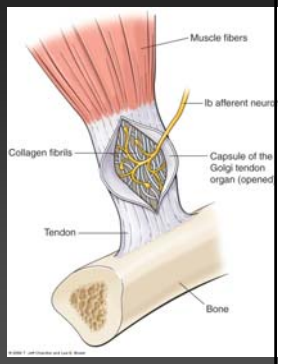
Agonist/ Antagonist Groups

- Agonist – muscle that causes or supports the movement of interest
- Antagonist – muscle or muscle group that act against the agonists



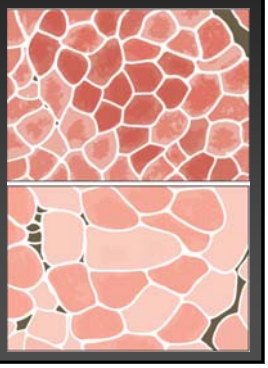
Golgi Bodies

- Located in tendons
- Sense change in force
- Provide feedback to CNS
- Too much force – shuts down muscle and all agonists
- Safety measure



Muscle adapts to stress…

- Neuro-muscular changes
  - ✓ Coordinated firing of MUs
  - ✓ Recruitment of more MUs
  - ✓ Relaxation of antagonists
- Hypertrophy
  - ✓ Increases in fiber size
  - ✓ More actin and myosin
- Hyperplasia
  - ✓ Increases in fiber number?
  - ✓ Evidence does not support



Can fibers change type?

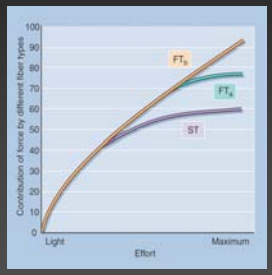
- Short answer – NO!
  - Type I to Type II
- However, some ability to transfer within type
  - Type IIa to Type IIb
  - Type IIB to Type IIa
- What fiber type does an athlete have?

Metabolic and Hormonal Adaptations

- Increased energy stores
  - Phospocreatine (CP), ATP, glycogen
- Increased levels of testosterone and growth hormone after strength training (acute)

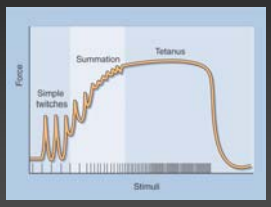
Control of Force – Recruitment

- Size Principle: Recruit larger and stronger motor units as force needs increase
  - Low force/ precision – smaller, slow twitch motor units
  - High force/ gross – larger, stronger fast twitch motor units



Control of Force – Rate Coding

- Force in a muscle can increase by increasing the rate of stimulation by CNS
- One pulse → twitch
- Many pulses → tetanus, fully contracted

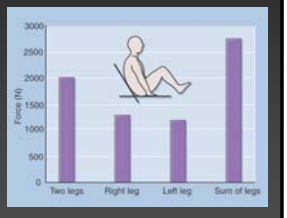


Muscular Phenomena – Cross Training

- Training of one limb can have transference to the other limb.
  - 60% transfer
- Specificity
  - Ex. leg to leg, not leg to arm
- Theories?
  - Bilateral activation of same muscle groups
  - Stabilization

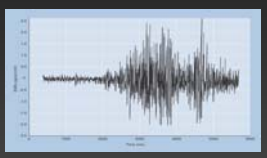
Muscular Phenomena – Bilateral Deficit

- Strength produced in a bilateral effort is not equal to sum of both sides individually
- Inhibitory mechanism?
- Speed of motion
- Level of activation



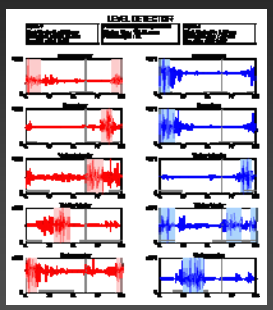
Electrical Activity - EMG

- Electrodes pick up electrical activity associated with contraction.
- Magnitude often proportional to strength of contraction
- Cautions…



Uses of EMG

- Determine when muscles are on/ off
- Compare timing
- Relative level of activation
  - Within a testing session



Muscle Identification Exercise

Using the movement description you developed earlier in the unit, identify and list the muscles you think are active in each phase of the movement. Next to each muscle, identify the function the muscle serves – e.g. flexes the shoulder, internally rotates the leg, contracts isometrically to stabilize the shoulder blade, etc. Submit the exercise in the appropriately named dropbox.