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The Limits of Human Strength

UNIV 197K-01
The Limits of Human Performance
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Kinesiology

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What does it mean to be "strong"

- Nearly all of our joints move by rotating
- A torque is necessary to produce rotation
- Therefore, being strong means being able to generate large torques at your joints
- From physics, torque (T) equals force (F) times distance (d) [d is also called the 'moment arm']

$$T = F\,d$$

- So, how do we relate this to human joints?

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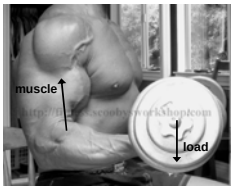
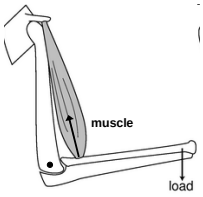
Human Joint Torque





- The dumbbell (load) creates a torque that tends to extend the elbow (CW)
- This is countered by the muscle, which creates a torque that tends to flex the elbow (CCW)

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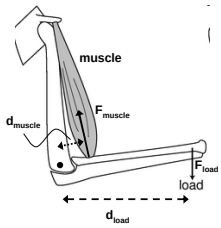
Human Joint Torque



$\Sigma T = 0 \Rightarrow T_{muscle} - T_{load} = 0$

so, $T_{muscle} = T_{load}$

and, $(F\,d)_{muscle} = (F\,d)_{load}$

Note that d_{load} is >> than d_{muscle}, so F_{muscle} must be >> than F_{load}!

- To increase strength you need larger muscle moment arm, more muscle force, or both

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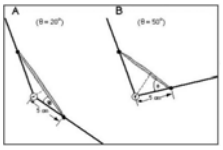
Muscle Moment Arm

- Moment arm is determined by the arrangements of your muscles, tendons, bones, and joints
- Muscle moment arm ***does*** change as you move your joint

Changes in biceps moment arm with elbow joint angle



- However, muscle moment arm ***does not*** change much, if at all, with training

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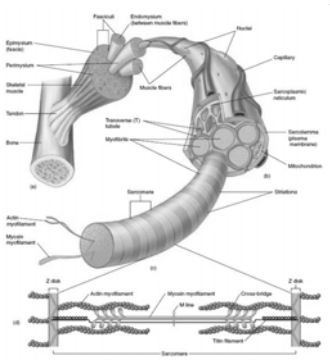
Muscle Structure

- Muscle
- Fascicle
- Fiber (cell)
- Myofibril
- Sarcomere
- Myofilaments
  - Actin (thin filament)
  - Myosin (thick filament)



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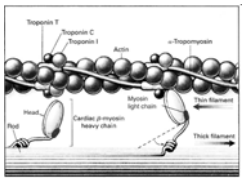
Muscle Force

Force and motion are the result of cross-bridge formation between actin (thin) and myosin (thick) filaments



- Each crossbridge produces 0.000000000004 newtons of force, and can shorten the muscle by 0.000000011 meters
- Large muscles can produce >1000 newtons of force, and can shorten by several centimeters

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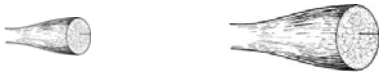
Muscle Hypertrophy

- Muscle force is proportional to the amount of contractile protein found in cross-section



small cross-section = weak muscle **large cross-section = strong muscle**

- Resistance exercise is one of several stimuli that cause muscles to increase in cross-sectional area
  - This process is known as *hypertrophy*
- Muscle hypertrophy is the result of genetic up-regulation of processes that lead to *protein synthesis*

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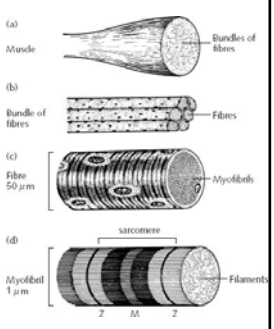
Muscle Hypertrophy

- Inside the muscle fibers (cells)
  - Existing myofibrils gain additional contractile proteins
  - At a certain size, myofibrils split, allowing each to incorporate more contractile material
- As the myofibrils increase in size and number, the fibers get larger in cross-section
- However, the total number of muscle fibers remains nearly constant with training



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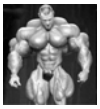
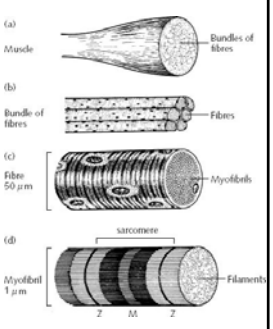
Muscle Hypertrophy

- There appears to be a maximum size that muscle fibers can grow to
  - This ultimately sets a limit on the amount of hypertrophy that is possible
- Despite this limitation, incredible increases in muscle size and strength are indeed possible





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The Neural Component

- To generate force, muscles must be activated by the nervous system
- Neural factors definitely influence muscle force
  - Changes in strength during the first few weeks of training are almost entirely neural in nature
- Neural adaptations that affect muscle force
  - Enhanced muscle recruitment
  - Increases neural firing rates
  - Improved neural coordination
  - Greater synchronization of activation

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Up next ...

- Factors that determine and limit human endurance