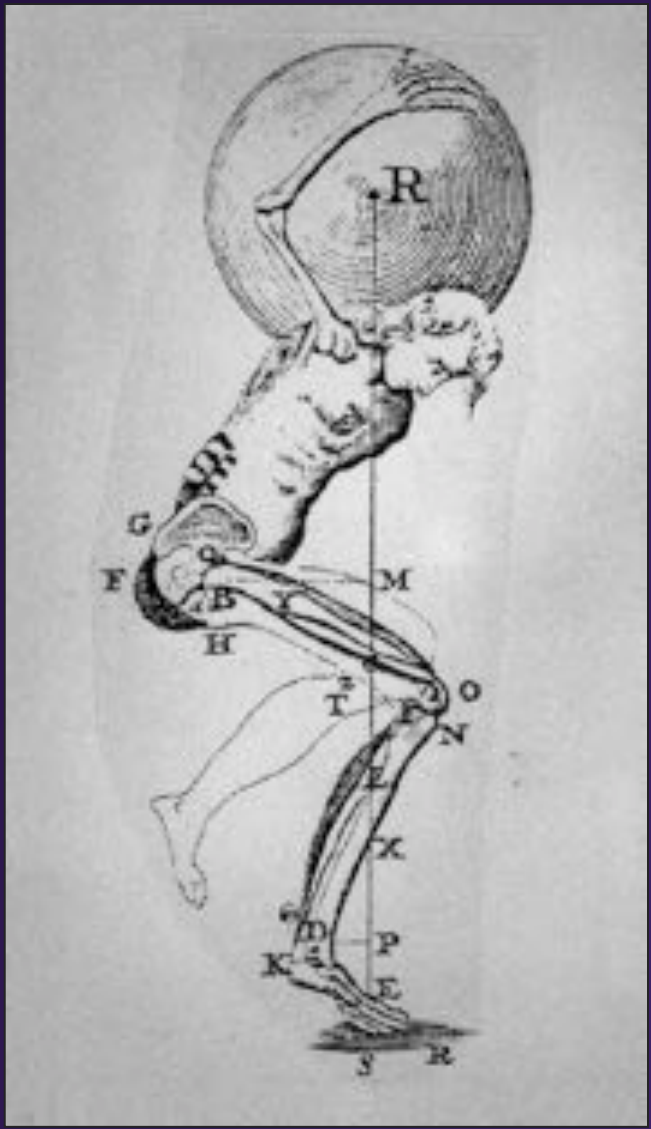


Musculoskeletal Biomechanics

BIOEN 520 | ME 527

Session 15B

Biomechanics of the Upper Extremity (Elbow & Wrist)

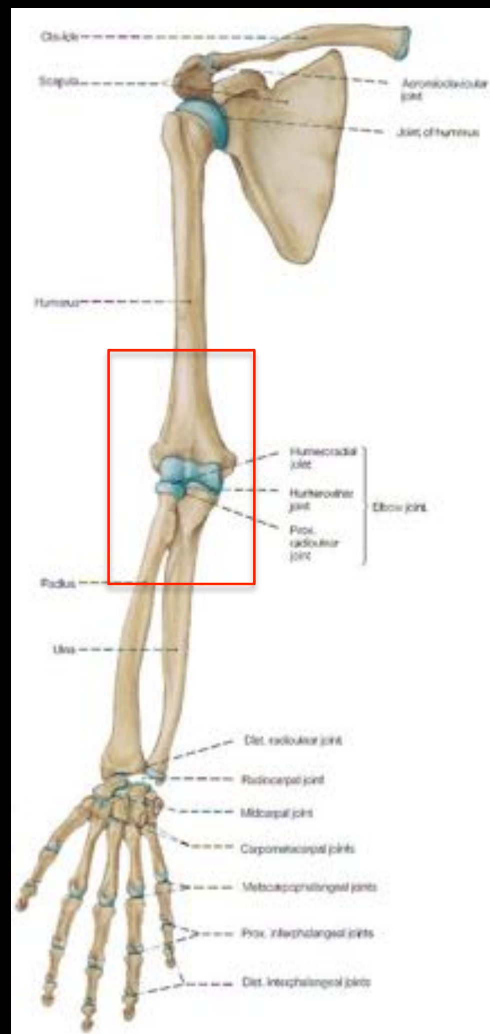
Session 15B HW #2 Questions (Elbow)...

[Q1]: Describe the functional anatomy of the elbow joint and how is it similar/different from the knee?

Elbow Anatomy

Brian Cook

- Humerus
- Ulna
- Radius

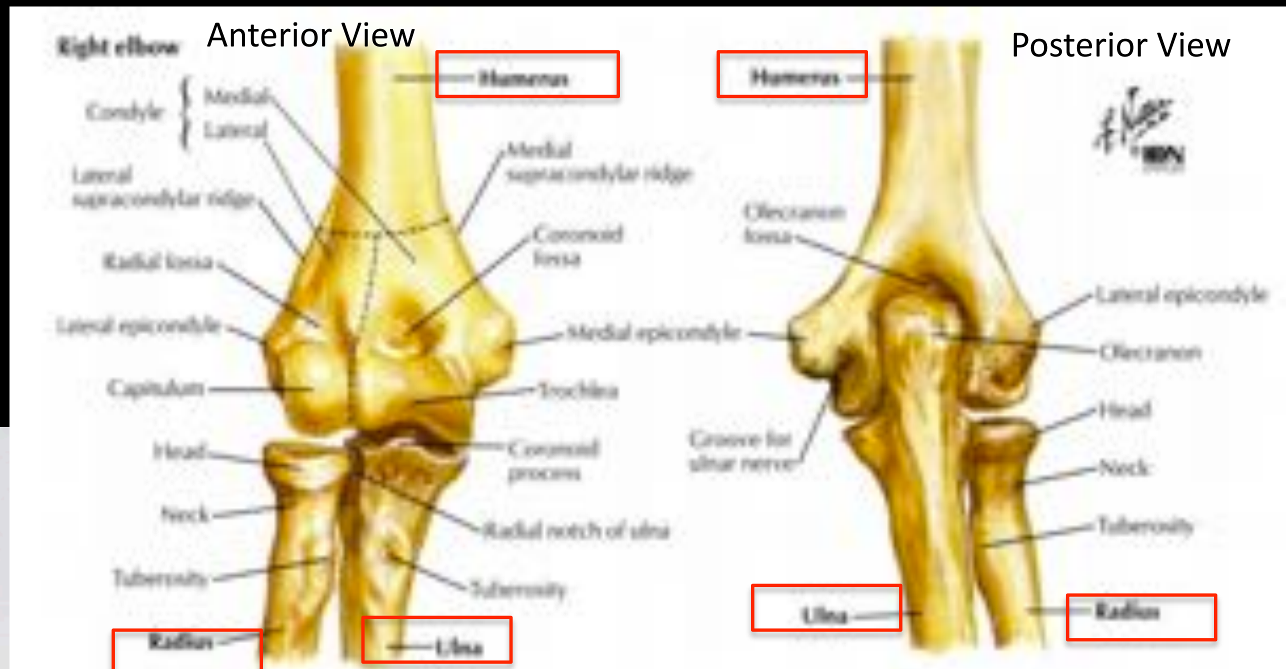


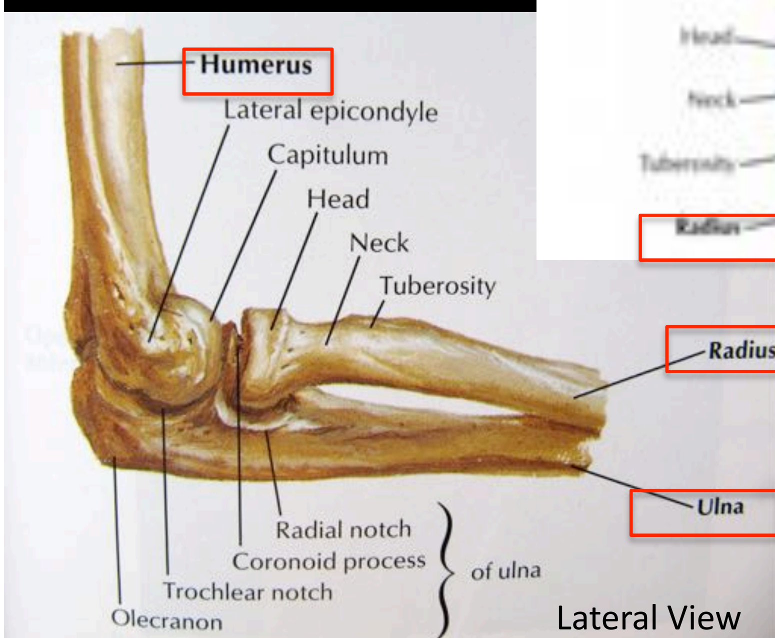
anatomt.com

Elbow Anatomy

Brian Cook

- Humerus
- Ulna
- Radius



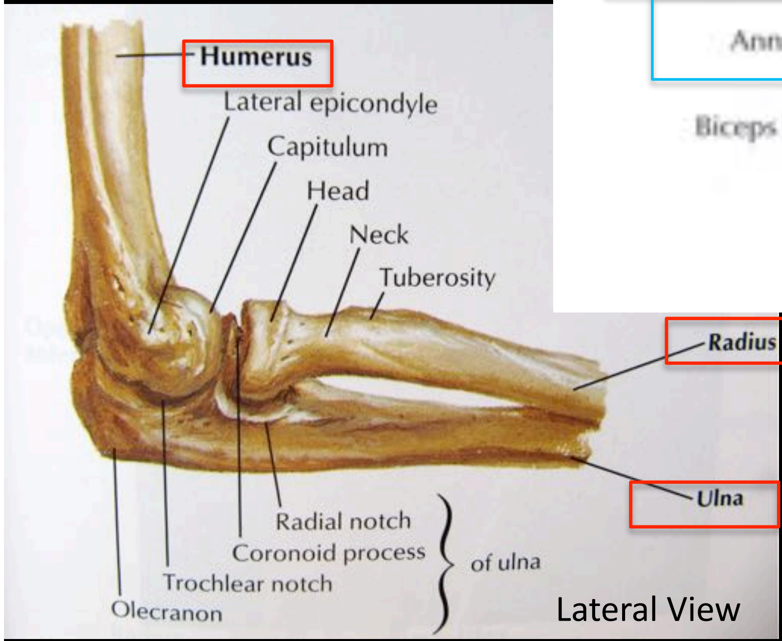


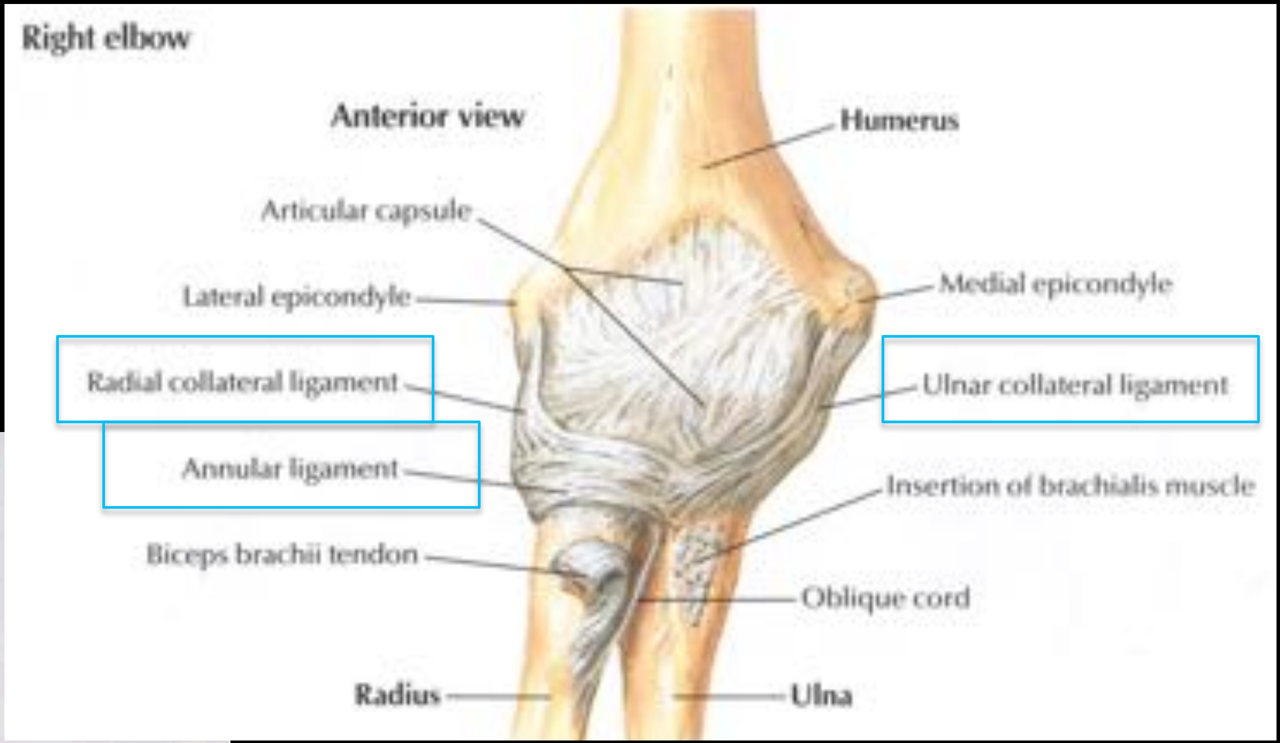
Netter, F. *Atlas of Human Anatomy.* 2014

Elbow Anatomy

Brian Cook

- Humerus
- Ulna
- Radius





- Collateral ligaments
- Annular ligament
- Joint capsule

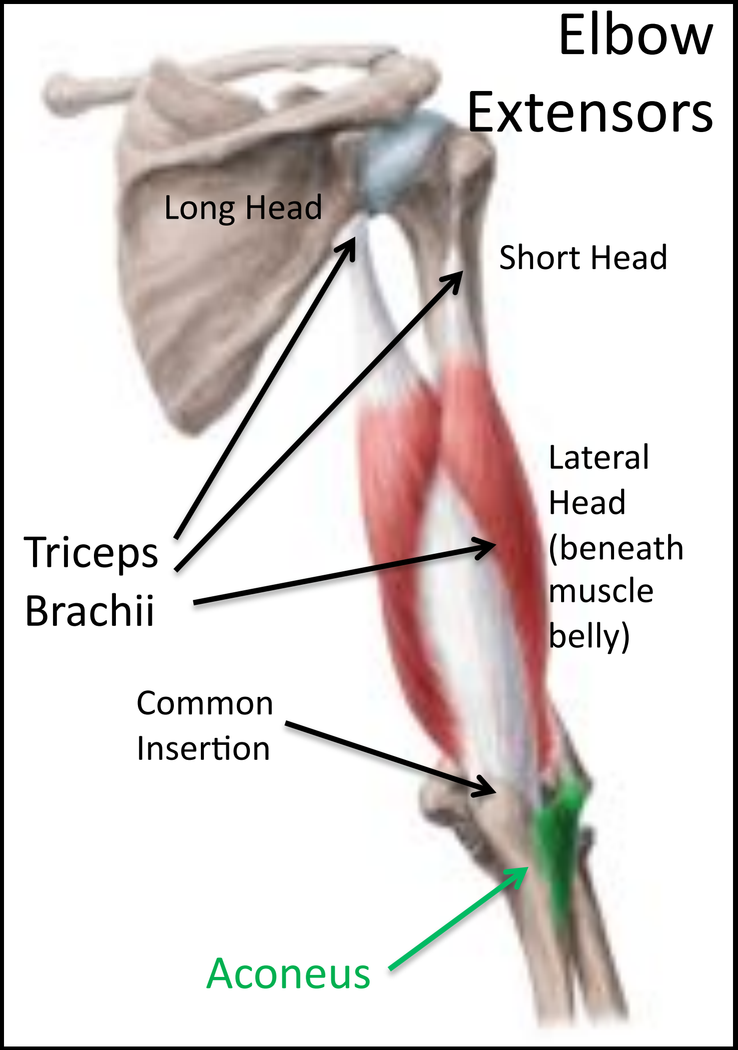
Netter, F. *Atlas of Human Anatomy.* 2014

Elbow Motion

- Flexors
  - Biceps brachii
  - Brachialis
- Extensors
  - Triceps brachii
  - Aconeus

Elbow Motion

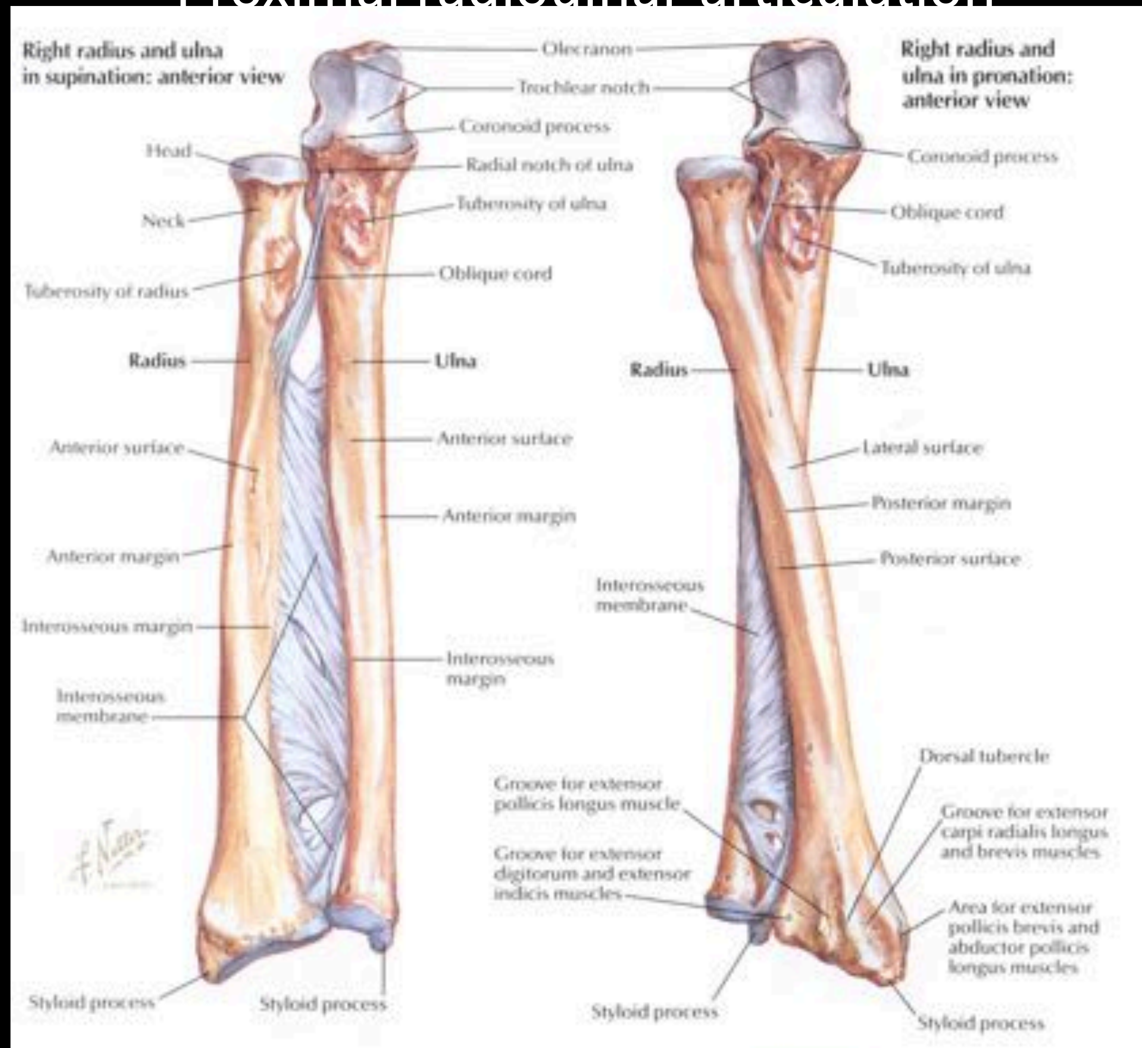
- Flexors
  - Biceps brachii
  - Brachialis
- Extensors
  - Triceps brachii
  - Aconeus



Elbow Motion

Proximal radioulnar articulation

- Flexors
  - Biceps brachii
  - Brachialis
- Extensors
  - Triceps brachii
  - Aconeus



Difference between elbow and knee

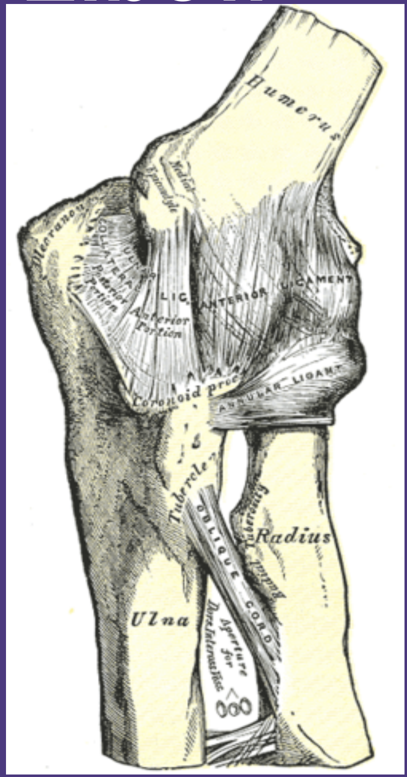
- Both hinge joints
- No sesamoid bone in elbow
- Elbow has articulations between humerus and ulna and radius
- Knee only has articulation between femur and tibia

http://www.kidport.com/

Session 15B HW #2 Questions (Elbow)...

[Q2]: How has the force distribution across the elbow joint been measured biomechanically and at what position(s) are they at the maximum?

Force Distribution Through the Elbow



Analytical Models require knowledge of:

- The muscles crossing the joint
- the physiologic cross-sectional area
- the moment arm
- the line of pull
- the muscle activity during motion
- the number of muscles involved.

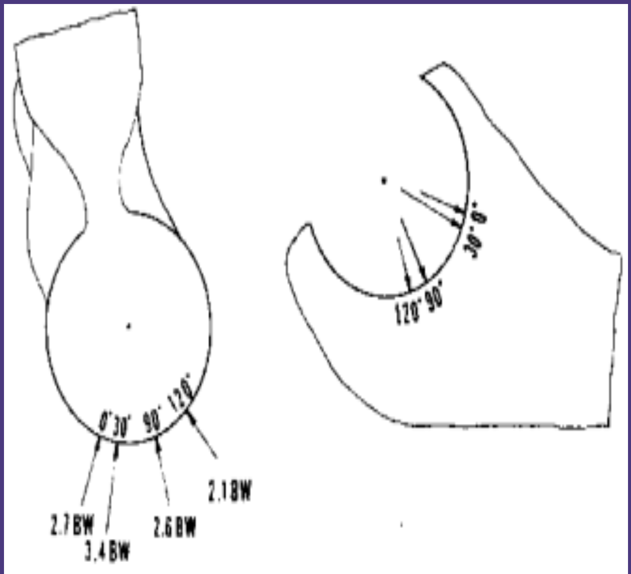
Results:

With extension and axial loading, the distribution of stress is 40% across the ulnohumeral joint and 60% across the radiohumeral joint.

Stefan F, Ranjan G, Thay Q.Lee, Anatomy and Biomechanics of the Elbow Joint, University of California, Irvine, CA

Force Transmission in the Ulnohumeral Joint

- <u>**The joint force**</u> transmitted in the ulnohumeral joint can range from one to three times body weight during heave lifting.
- <u>**The direction of the resultant joint force**</u> changes with flexion angle, pointing more anteriorly with elbow extension and posteriorly with elbow flexion.



Stefan F, Ranjan G, Thay Q.Lee, Anatomy and Biomechanics of the Elbow Joint, University of California, Irvine, CA

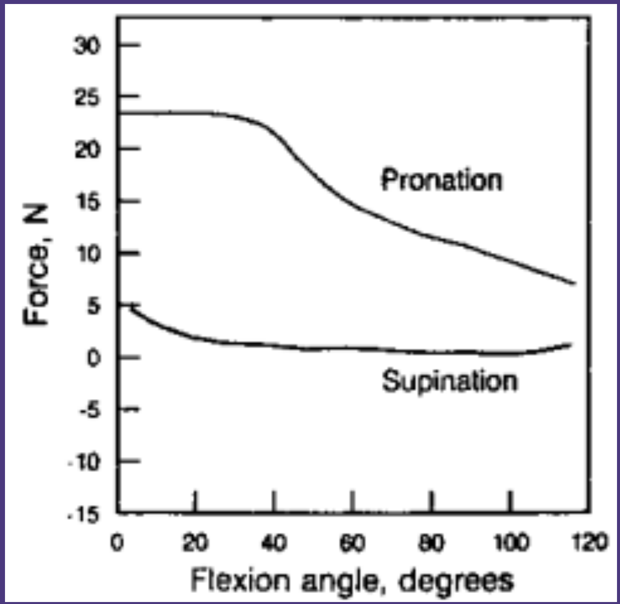
Force Transmission through the Radial Head

Experimental Methods:

- A force transducer was placed at the radial neck .
- a flexion force was applied through the brachialis and biceps muscles.
- The extension forces were passive.

Results:

- Radial head forces were greatest from 0° to 30° flexion and always higher in pronation.



Stefan F, Ranjan G, Thay Q.Lee, Anatomy and Biomechanics of the Elbow Joint, University of California, Irvine, CA

Session 15B HW #2 Questions (Elbow)...

[Q3]: What is meant by active stabilization of the elbow joint; what are active and passive stabilizers and why are they important?

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Stabilizers of the elbow joint

Mark Goldstein

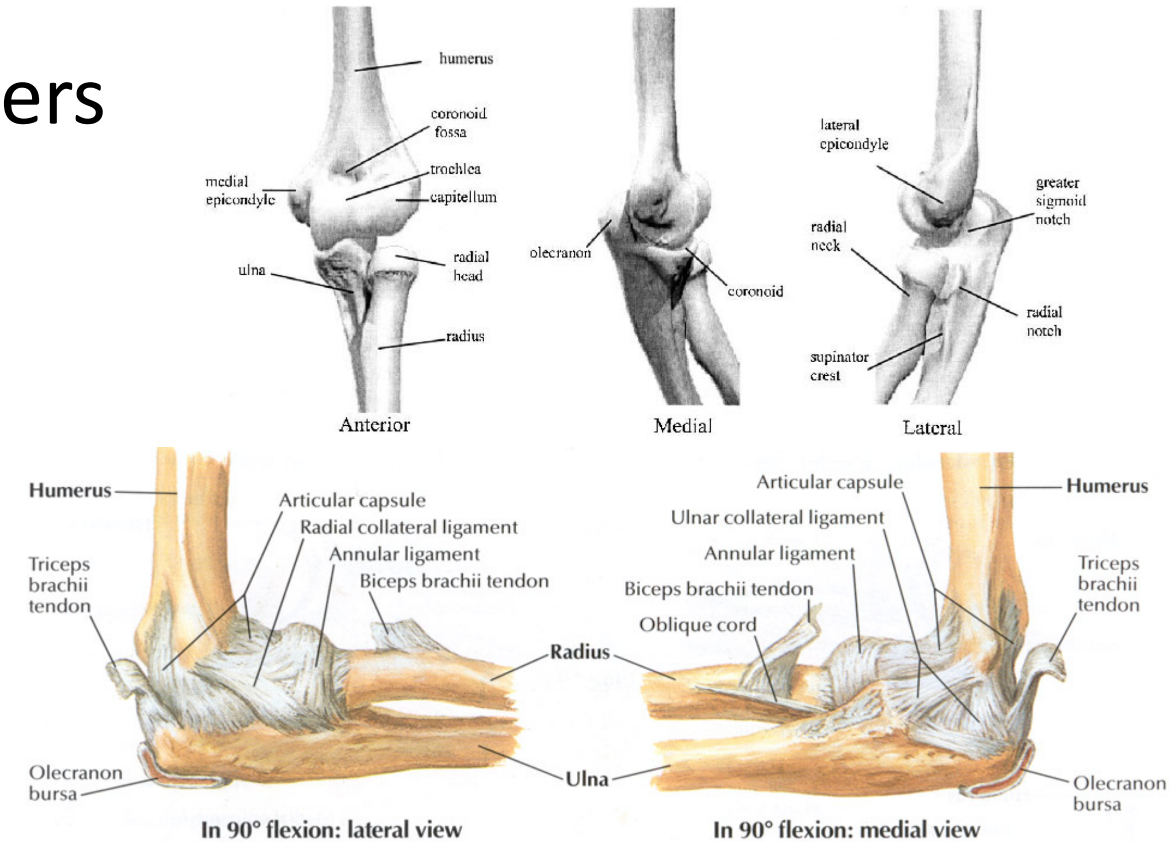
What is stabilization of the elbow joint?

- Active stabilization: created by compressive forces from musculature surrounding joint

- Passive stabilization: created by bony geometry and soft tissues crossing the joint.

Passive stabilizers

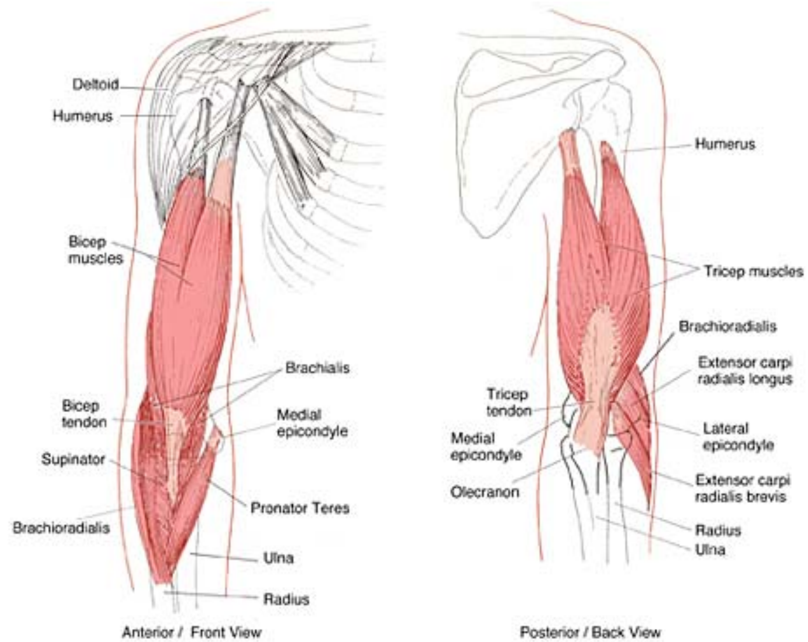
- Bony geometry
  - Ulnohumoral joint
- Soft tissues
  - Joint Capsule
  - Ulnar collateral ligament
  - Radial collateral ligament



Fornalski et al. 2003

Active stabilizers

- Stabilize during contraction of flexors/extensors
- Lateral compartment
  - Forearm flexors
- Medial compartment
  - Forearm extensors, pronator teres
- Proximal stabilization



Fornalski et al. 2003

Session 15B HW #2 Questions (Elbow)...

[Q4]: Describe the carrying angle for the elbow, how does it compare to the "Q" angle for the knee, and why is it different between males and females?

Describe the carrying angle for the elbow, how does it compare to the "Q" angle for the knee, and why is it different between males and females?

- Q angle (Review from Session 14B)
  - Quadriceps angle in the lower limb
  - Measure using the ASIS on ilium to patella, and patella to tibial tuberosity
  - Value varies from 6-27^{o}, average of 15 ^{o}
  - Measured while standing can increase angle 1-3 ^{o}
  - Women have ~4.6^{o} larger than men
  - Higher angle increases risk injury/pain (e.g. ACL injury, chondromalacia patella/ patellafemoral pain syndrome)

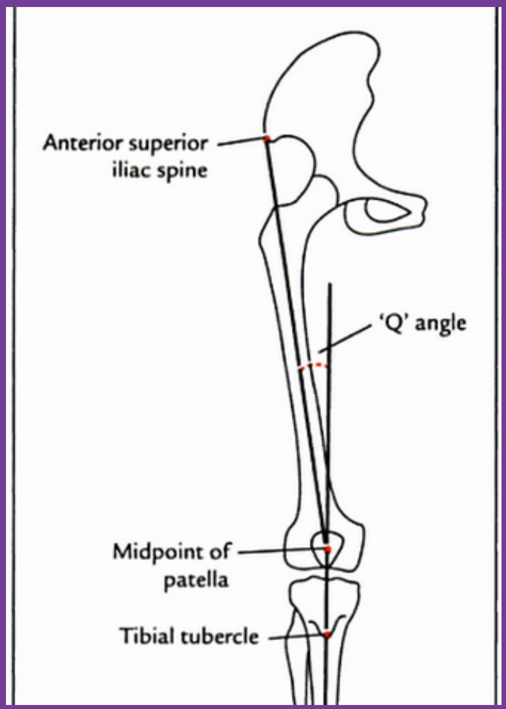


Image sources: http://www.physio-pedia.com/images/f/f2/Q_angle_2.png

Describe the carrying angle for the elbow, how does it compare to the "Q" angle for the knee, and why is it different between males and females?

- Carrying Angle
  - Angle between the midline of the upper arm and the midline of the lower arm.
  - Average angle 12.88 ^{o}± 5.92^{o}
  - Varies with method of measurement
    - Goniometry: 13.0 ^{o} ±3.0^{o}
    - Radiography: 10.1^{o} ±4.5^{o}
  - Higher angle increases risk injury/pain (e.g. elbow dislocation, elbow instability, elbow fracture when falling, entrapment neuropathy of ulnar nerve)

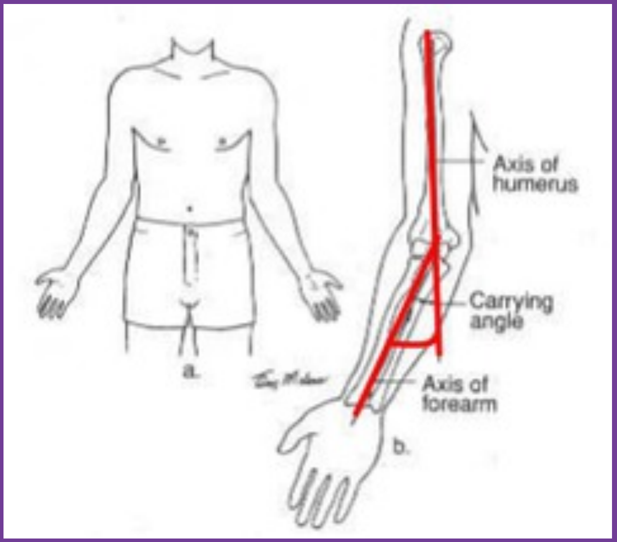


Image sources: http://o.quizlet.com/0f93jQaJCRbL01r3hYaniA_m.jpg

Describe the carrying angle for the elbow, how does it compare to the "Q" angle for the knee, and why is it different between males and females?

Variations	**Typically Higher Angle**	**Typically Lower Angle**	**Potential Reasons**
Gender	Female (10.97 º ± 4.27º)	Male (15.07 º ± 4.95º)	• Increased ligamentous laxity in women • Females tend to have narrow shoulders and wider hips, larger angle helps with arm swing
Age	Older-Adults	Younger -Children, under ~15yrs (Increase about .42-.6 degrees per year)	• Increase about .42-.6 degrees per year • Increased use? • Skeletal Maturity?
Hand/Arm Dominance	Dominate Side	Non-Dominate Side	• Increased use?

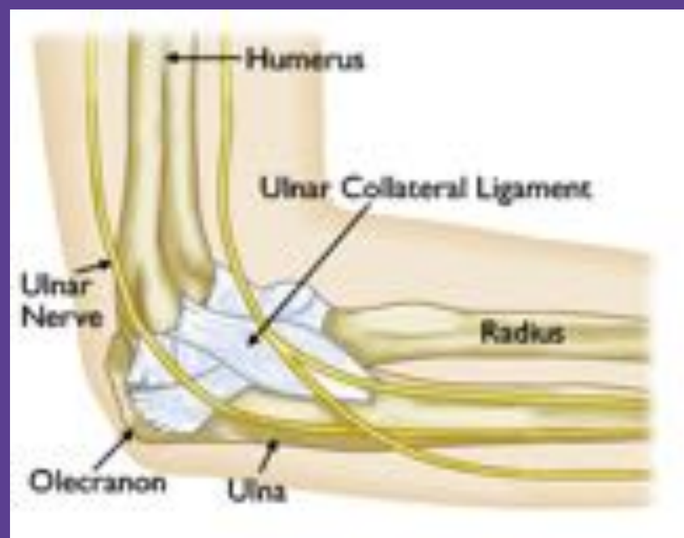
Session 15B HW #2 Questions (Elbow)...

[Q5]: What are common traumatic and overuse injuries to the elbow and how are they treated/repaired?

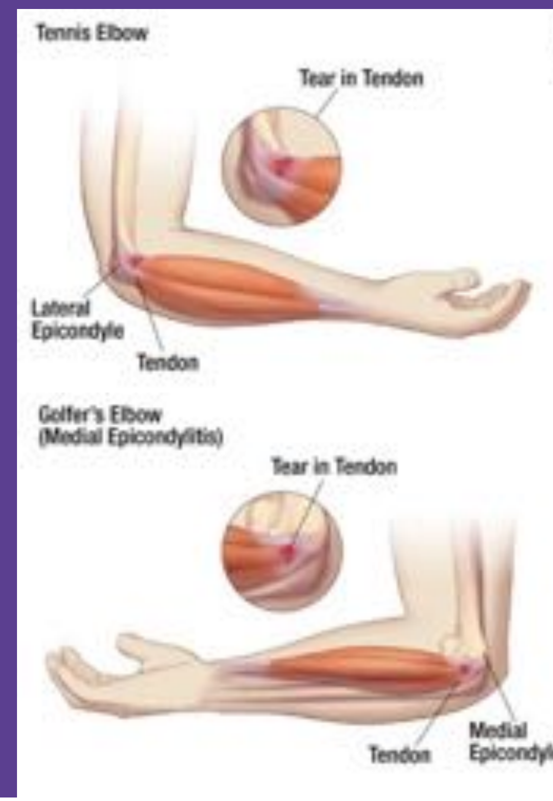
Common elbow overuse injuries

Bursitis

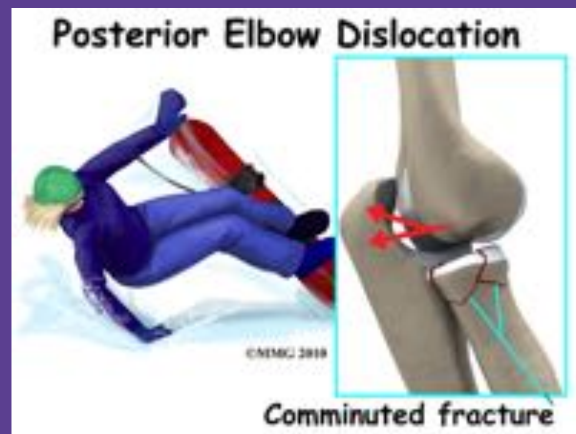
Neuropathy entrapment/compression



Tendonitis



Common elbow traumatic injuries



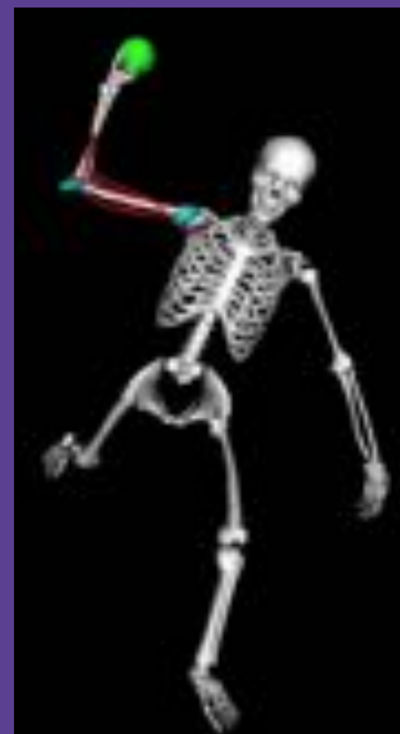
Wikipedia

Tom Lawrence, MD

Elbow injury biomechanics research

- Sport injury prevention
  - Tennis grip
  - Youth baseball pitching mechanics

- Post-traumatic reconstruction
  - Joint congruity
  - Range motion



Wendy Murray
Northwestern University

OrthoFix

Session 15B HW #2 Questions (Elbow)...

[Q6]: What is "Tommy John" surgery (provide sports context), and what biomechanical factors have been studied towards optimizing the reconstruction?

Ulnar Collateral Ligament Reconstruction
Tommy John Surgery

Corey Pew, ME 527 HW 2, Winter 2016

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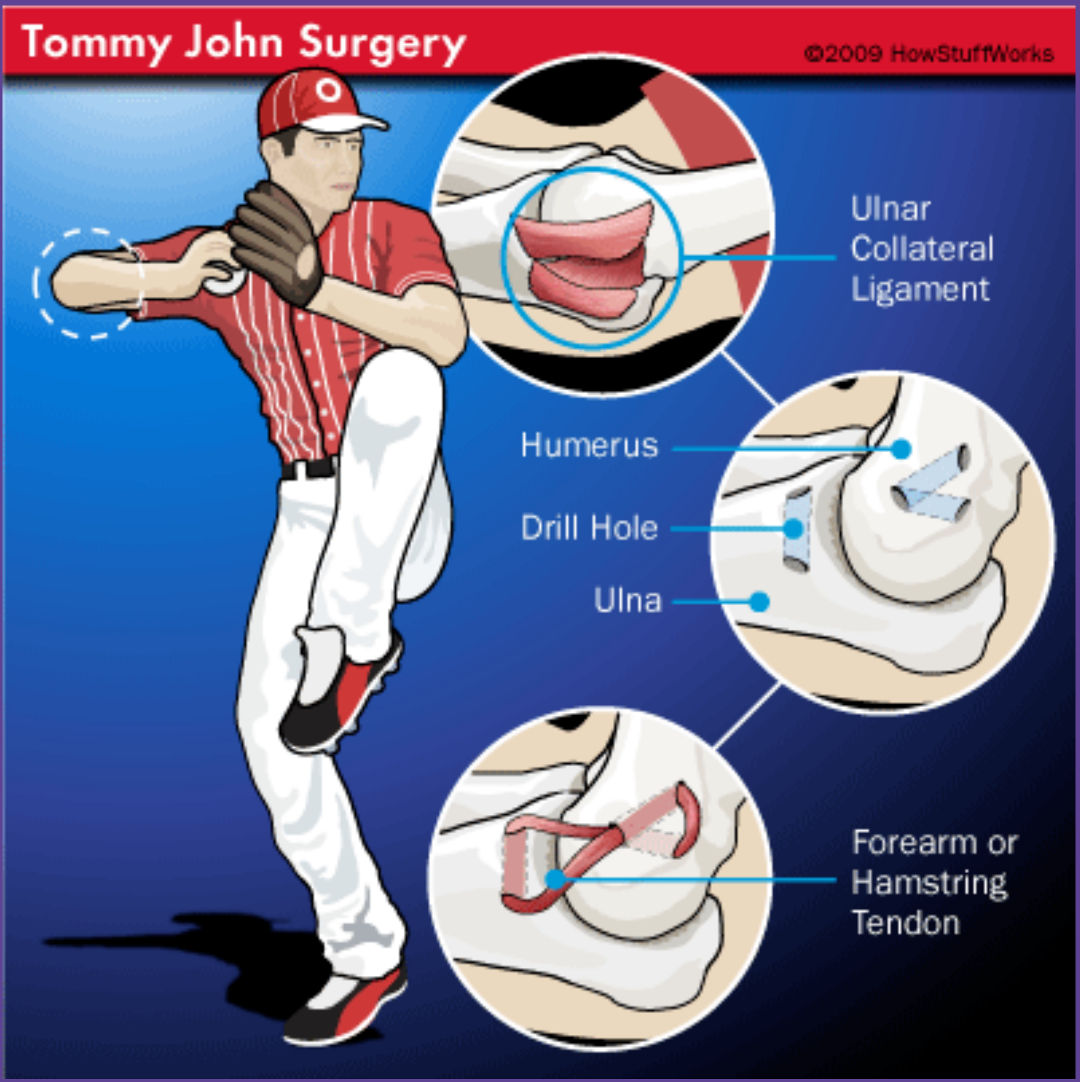
Background

- Ulnar Collateral Ligament (UCL) primary elbow support to valgus stress
- Commonly damaged in overhead athletes, primarily baseball pitchers, but can also occur during acute elbow dislocation
- 16% of active professional pitchers have received the UCL reconstruction
  - Only 83-89% return after procedure
- First attempted in 1974 by Dr. Frank Jobe on Major League Pitcher Thomas Edward John Jr.

Anatomy of UCL Reconstruction



http://health.howstuffworks.com/medicine/modern-technology/surgery-change-baseball1.htm

Biomechanics

- During Professional Pitch
  - Peak UCL force when elbow at 90°, shoulder at maximum external rotation
  - Elbow torque reaches 64-90 Nm
  - UCL accounts for 50 Nm of this torque
  - Cadaver studies show UCL can support 32 Nm
  - Often associated with late arm cocking
- Reconstruction
  - Hole Position
    - Lever Arm – Generally use UCL insertion points
    - Sufficient Bone Bridge – Prevent breakage
  - Tendon replacement
    - Palmaris, but others used based on availability (hamstring)
    - Preload set at 30° elbow angle to "sufficient" tension
- Post surgery and recovery - No significant difference found in elbow and shoulder range of motion, velocity, torque, or force between UCLr pitchers and control group
  - No data for pitchers before surgery
  - Only data for pitchers that fully recovered

Questions?

References:

1) E. Cain et al., Am J Sports Med, **38**(12):2426-34, 2010
2) J. Dugas et al., Sports Med and Arthroscopy Rev, **22**(3):169-82, 2014
3) G. Fleisig et al., Am J Sports Med, **43**(5):1045-50, 2015

Session 15B HW #2 Questions (Wrist)…

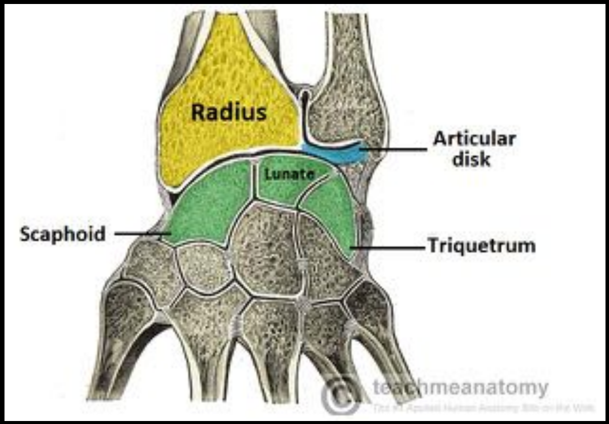
[Q7]: Describe the functional anatomy of the wrist and how is it similar/different from the ankle?

Functional Anatomy of the Wrist Joint

Ty Youngblood
BIOEN 520 / M E 527
February 23, 2016

Wrist Joint Structure

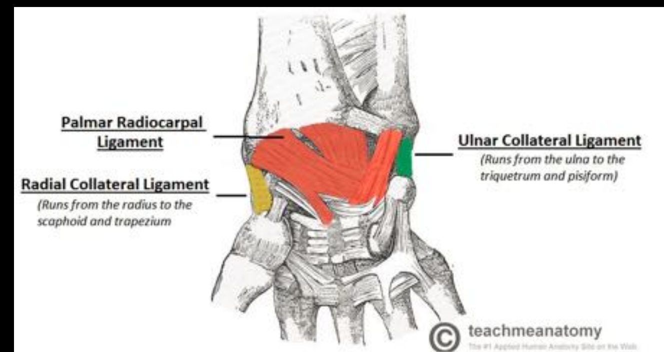
- The wrist joint (radiocarpal joint) is a synovial joint marking transition between the forearm and hand
- Carpal bones form a convex surface, which articulates with the concave surface of the radius and articular disk
- Articulating Surfaces
  - **Distally** – proximal row of the carpal bones (except the pisiform)
  - **Proximally** – distal end of the radius, and the articular disk
  - **The ulna is not part of the wrist joint** – articulates with the distal radius
    - Articular disk

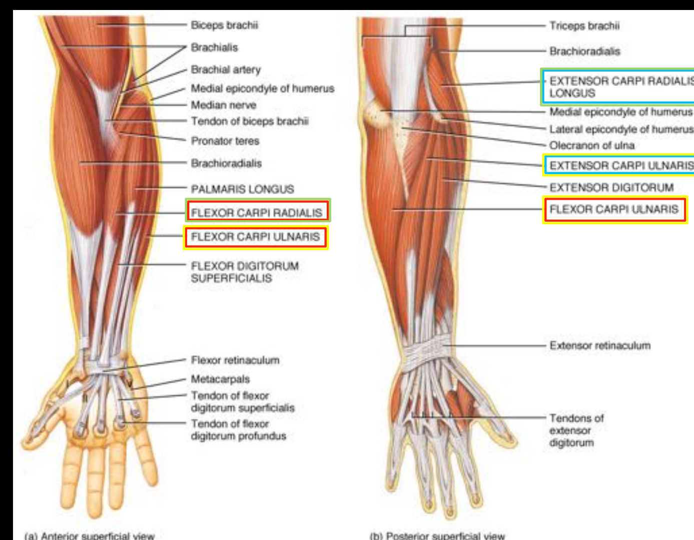


http://www.anatomybox.com/wrist-x-ray/

Stability & Movement

- Joint Capsule
  - Fibrous outer layer – radius, ulna, proximal carpals
- Ligaments
  - Palmar radiocarpal
  - Dorsal radiocarpal
  - Ulnar collateral
  - Radial collateral
- Ellipsoid/Condylar type joint
  - Flexion, extension, adduction, and abduction
- Controlled by muscles of the forearm





https://noexcuseshealth.wordpress.com/2013/03/20/forearm-exercise-reverse-wrist-curls/

Comparing the Wrist and Ankle Joints

- Similar anatomical constructs
  - Synovial joints
  - Connected to two long bones
  - Proximal component – Carpus/Tarsus
  - Middle portion – Metacarpus/Metatarsus
  - Terminal component – Phalanges
- Different functions
  - Foot – basis of support for body = solid build, less movable components
    - Hinge Joint
  - Size and angle of the carpus and tarsus

http://clinicalgate.com/ankle-and-foot/

Session 15B HW #2 Questions (Wrist)...

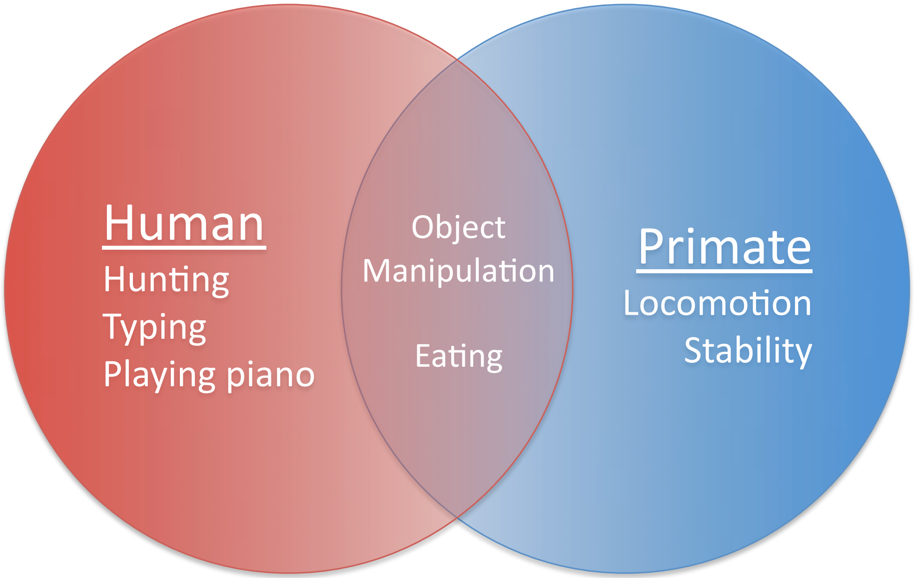
[Q8]: What are the ranges of motion of the human wrist and how do they differ from ("knuckle-walking") non-human primates?

Ranges of motion of human & non-human primate wrists

- Methods
  - Subjects:
    - Various species
  - Data collection
    - Radiography
    - Bone pins
    - Markerless tracking
    - Goniometers

Fig. 1 – *Ex-vivo* experimental subject[4].

Functions



1. Orr C, et al. *The Anat Rec* **293**, 692-709. 2010.

Ranges of motion of human & non-human primate wrists

- Ranges of motion

Table 1 – Range of ROM from multiple studies[1,2,3]

Planar motion (degrees)	Human (min – max)	Primate (min – max)
Flexion	73-82	38-91
Extension	60-75	31-78
Radial Deviation (Abduction)	19-21	8-24
Ulnar deviation (Adduction)	33-36	17-44

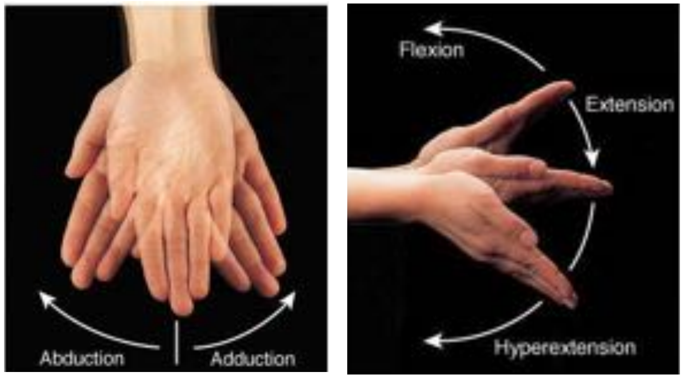


Fig. 1 – Wrist Motions[4].

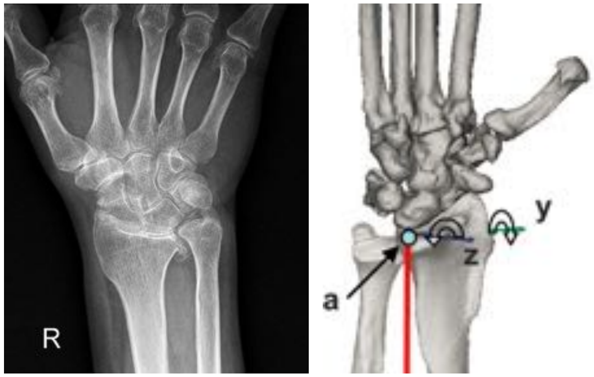


Fig. 2 – Comparison of human (left) and primate (right) wrists[1,5].

1. Orr C, et al. *The Anat Rec* **293**, 692-709. 2010.
2. Ryu J, et al. *J Hand Surg*. 1990.
3. Daver G, et al. *J Anatomy* **220**, 42-56. 2012.
4. http://classroom.sdmesa.edu/eschmid/chapter7-zoo145.htm
5. http://radiopaedia.org

Ranges of motion of human & non-human primate wrists

- Loading
  - Low in humans
  - High in knuckle-walkers
    - Higher volume of trabecular bone[1]
    - Larger carpal bones[1]
  - Increased wrist ROM = less inherent stability!

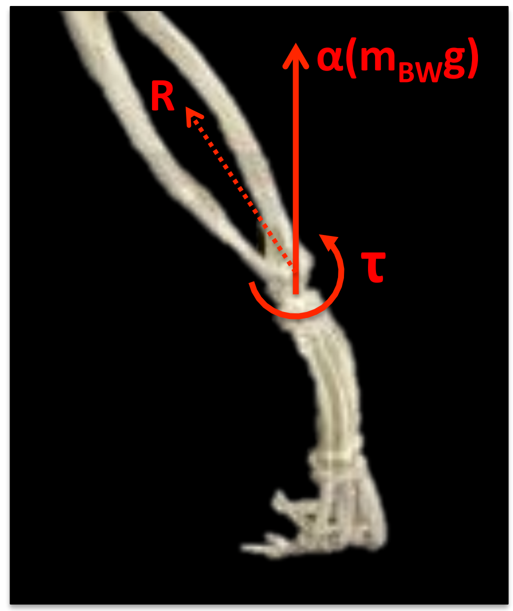


Fig. 1 – Comparison of human (left) and primate (right) wrists[2,3].

Fig. 2 – carpal bones[4].

1. Schilling AM, et al. *J Morpho* **275**, 572-585. 2014.
2. http://www.gettyimages.com
3. http://www.skullsunlimited.com
4. https://en.wikipedia.org/wiki/Carpal_bones

Session 15B HW #2 Questions (Wrist)...

[Q9]: What biomechanical studies have been performed to evaluate the forces transmitted across the wrist joint, and how are they distributed between the radius and ulna?

Studies on forces of wrist joint & Distribution between radius and ulna

Guangcan Lu

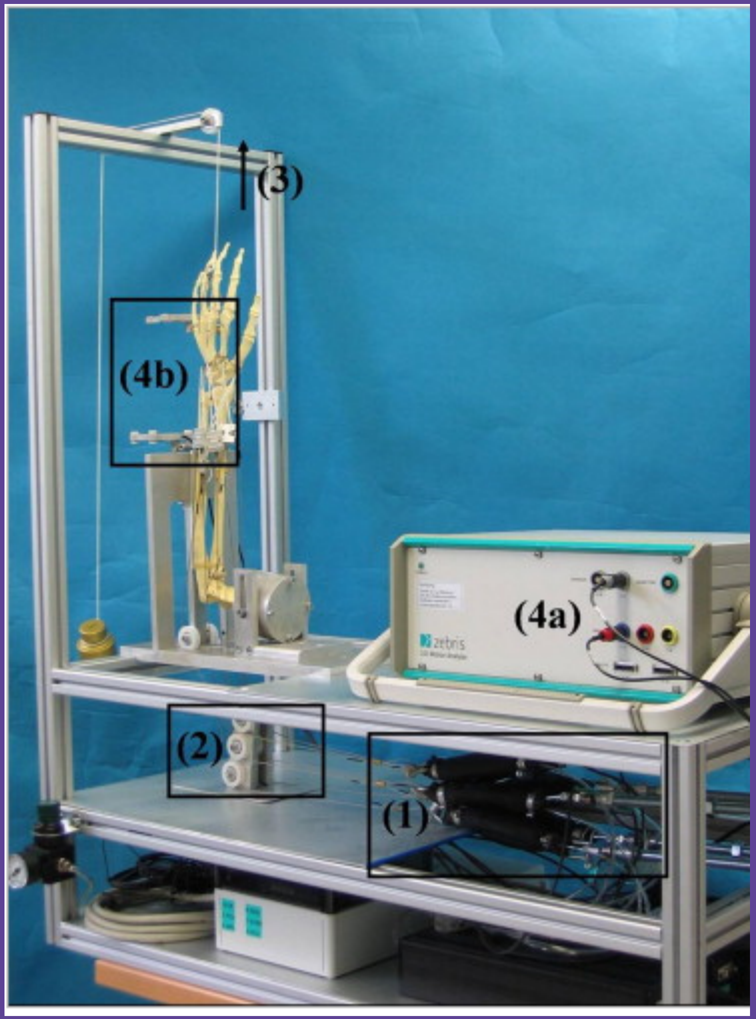
UNIVERSITY of WASHINGTON

1. Studies on forces of wrist joint

Stefanie Erhart， 2012

> **Measurement of intraarticular wrist joint biomechanics with a force controlled system**

> Muscle forces
> Intraarticular measurements
> Range of motion
> Tendon excursion

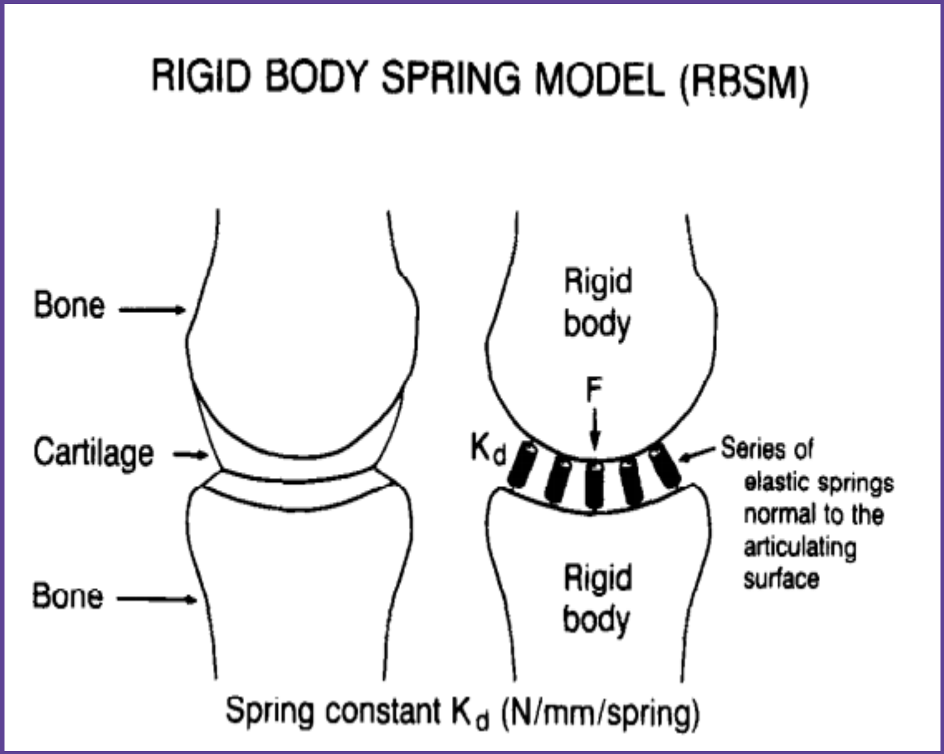


1. Studies on forces of wrist joint

F. Schuind，1995

> Force and pressure transmission through the normal wrist

A theoretical two-dimensional study in the posteroanterior plane



2. Distribution between radius and ulna

Mesh type	Load (N)			
	Radius	Ulna	Total	% shared by ulna
10-Node, coarse mesh	0.258	1.768	2.03	87.3%
10-Node, fine mesh	0.549	1.358	1.91	71.2%
4-Node, coarse mesh	0.266	1.777	2.04	87.0%
4-Node, fine mesh	0.686	1.268	1.95	64.9%

- 1.Finite element modeling
- 2.Material properties of bone
- 3.Ex vivo strain gaging

- Model validation
- Experimental comparison

Yunkai Lu, Ganesh Thiagarajan , Daniel P. Nicolella and Mark L. Johnson; 2012

Thank you!

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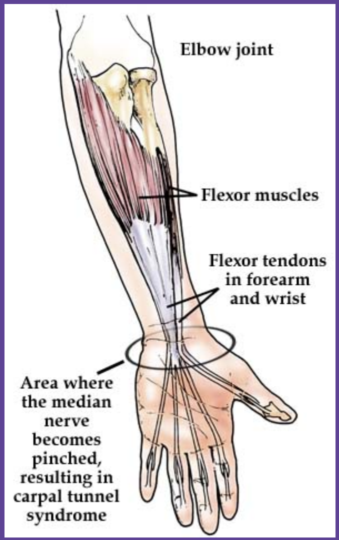
Session 15B HW #2 Questions (Wrist)…

[Q10]: What are common traumatic and overuse injuries to the wrist and how are they treated/repaired?

Wrist Injuries – Vijeth Rai

Overview



> Classified under 2 broad categories
- Overuse / Repetition
- Trauma
- Some overlap - TFCC etc.

> Overuse Injuries
- Caused by sports, work – awkward positions
- Inflammation of soft tissues caused by pinching, squeezing
- Tendinitis –de Quervain's tenosynovitis, ECU tendinitis
- Carpal Tunnel

> Trauma Injuries
- Sprain (ligaments) vs Strains (tendons) vs Bones
- Sprain > Grade 1 – stretched
  - > Grade 2 – partially torn
  - > Grade 3 - Completely torn
- Many ligaments but commonly injured Scapho-lunate, Triangular fibrocartilage complex tear
- Fractures, tendon strains

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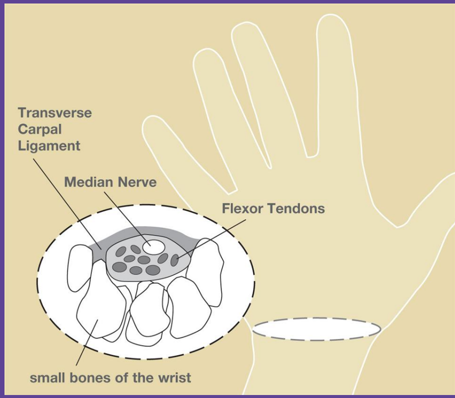
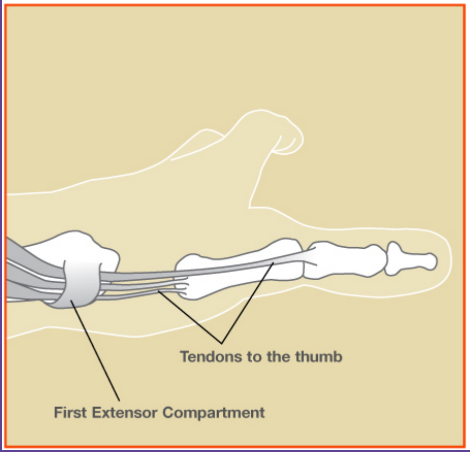
Overuse Injuries

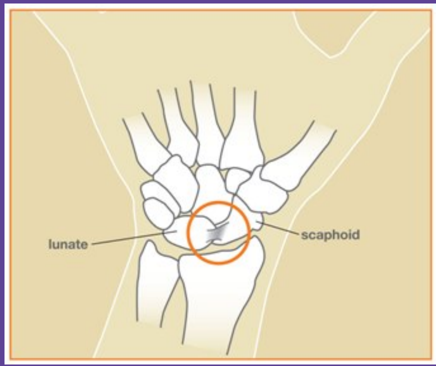


- Carpal Tunnel
  - Pressure on medial nerve inside the tunnel
  - Causes:
    - Awkward postures
    - Swelling of tendons tenosynovitis, fluid build up, diabetes
  - Symptoms: pain, weak grip, numbness, tingling
  - Treatment:
    - changing patterns
    - Splint
    - Steroid Injections – reduce swelling
    - Surgery in extreme cases – cutting ligament to relieve pressure

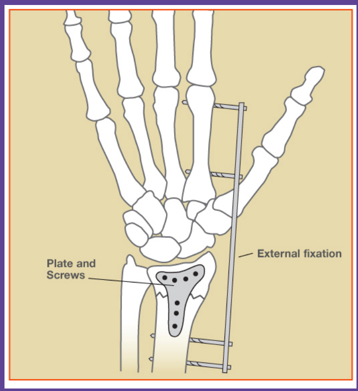
- Tendinitis
  - Inflammation of tendons.
  - Also, collagen degeneration, fiber disorientation, gylcosaminoglycans increase, vascular in-growth
  - Most common : de Quervain syndrome: tendons on the thumb
  - Causes : unknown – hormones, sports, poor warm up and postures
  - Symptoms: thumb flexion causes pain.
  - Treatment:
    - splint to prevent thumb and wrist motion, physiotherapy
    - NSAIDs, ibuprofen etc.
    - Corticosteroid injection into the 1st dorsal compartment
    - Surgery to make room for tendons
  - Others ECU tendinitis



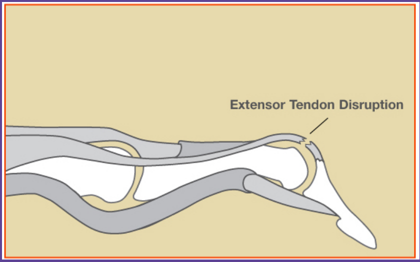
Trauma Injuries



> **Wrist Sprains**
- **Ligament tear**
- **Causes: Impact fall on outstretched hand**
- **Symptoms: Swelling, pain, discoloration, warm feeling around wrist**
- **Many ligaments but most common tear: Scapho Lunate Ligament (**scaphoid bone and the lunate bone)
- Treatment :
  > RICE – Rest, Ice, Compress, Elevate
  > Splint – 1 to few weeks
  > Surgery –
    - Pins to hold bones in place while healing,
    - Ligament reconstruction – tendon graft
    - Fusion – Bones fused
- Other common tears: TFCC (triangular fibrocartilage complex).



> **Wrist Fracture**
- **Any of the 10 bones**
- **Displaced vs Non Displaced**
- **Osteoporosis increases chances**
- **Symptoms: Pain and Swelling, restricted movement with pain**
- **Treatment: Splint/Cast ,Pins, screws etc.**



> **Tendon Injuries**
- **Extensor and Flexor tendon tears caused by deep cuts**
- **Symptoms: Cant bend fingers, resulting in mallet finger etc.**
- **Treatment: Mostly surgery**