The Biomechanics of the Human Upper Extremity

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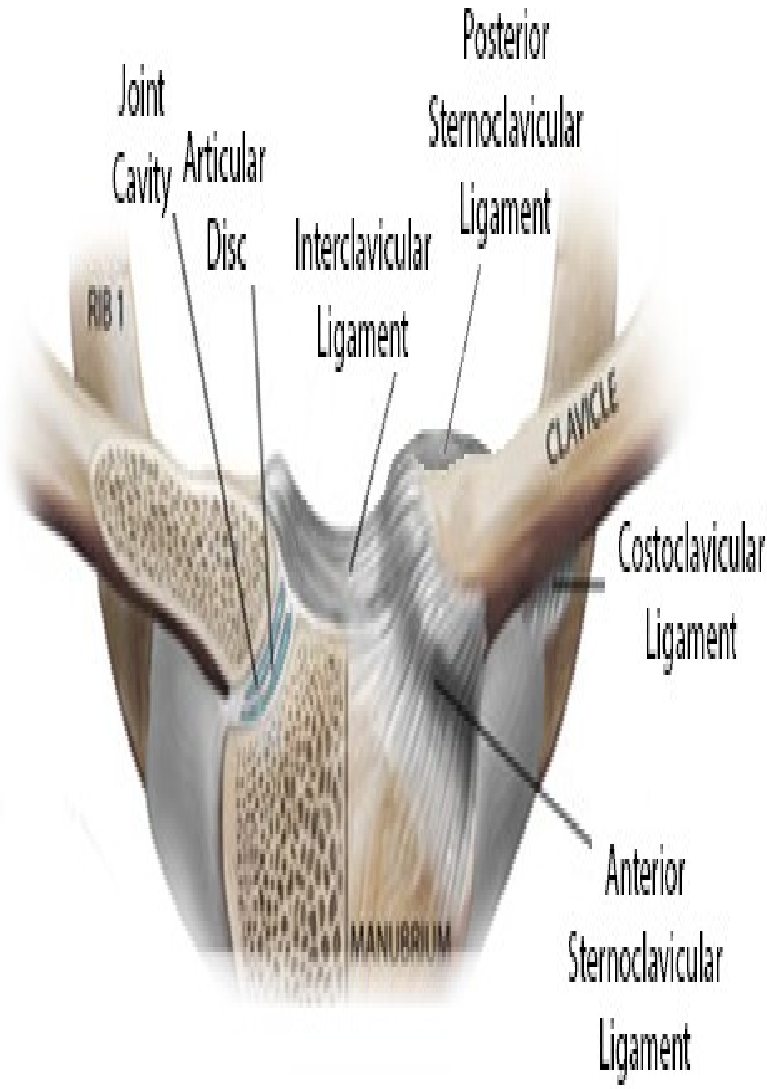
The sternoclavicular joint

- Joint between the manubrium of the sternum and the clavicle bone.
- Structurally classed as a synovial saddle joint and functionally classed as a diarthrosis and multiaxial joint.
- Composed of two portions separated by an articular disc of fibrocartilage.
- The bone are the sternal end of the clavicle, the upper and lateral part of the sternum, (the clavicular notch), and the cartilage of the first rib, visible from the outside as the suprasternal notch.

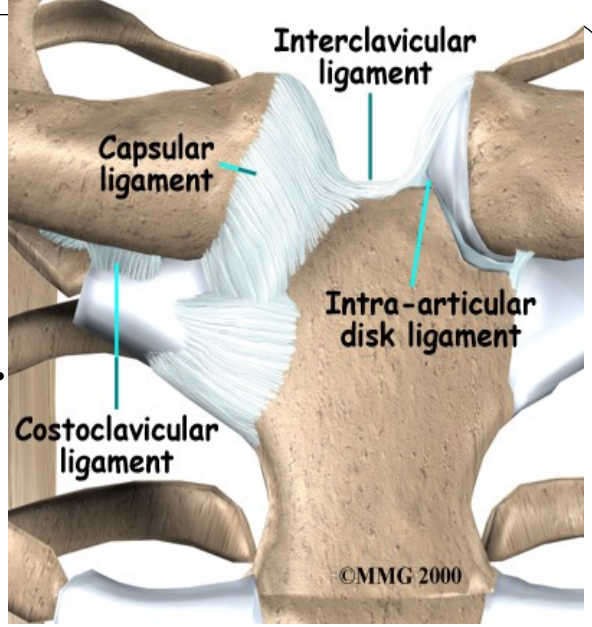
- Protected and stabilized by Joint capsule
- Anterior & posterior S-C ligaments
- Intra-articular disc
- Interclavicular ligament
- Costoclavicular ligament
- The articular surface of the clavicle is much larger than that of the sternum, and is invested with a layer of cartilage, which is considerably thicker than that on the sternum.



- **The costoclavicular ligament**

is the main limitation to movement,

and therefore the main stabilizer of joint.



- A fibrocartilaginous disc present at joint increases the range of movement.
- **Sternoclavicular dislocation is rare, but** may result from direct trauma to the clavicle or indirect forces applied to the shoulder.
- Posterior dislocations deserve special attention, as they have the potential to be life-threatening because of the risk of damage to vital structures in the mediastinum

Sternoclavicular Joint

- Provides major axis of rotation for movement of clavicle and scapula
- Freely permitted frontal and transverse plane motion.
- **Close pack** position is with maximum shoulder elevation

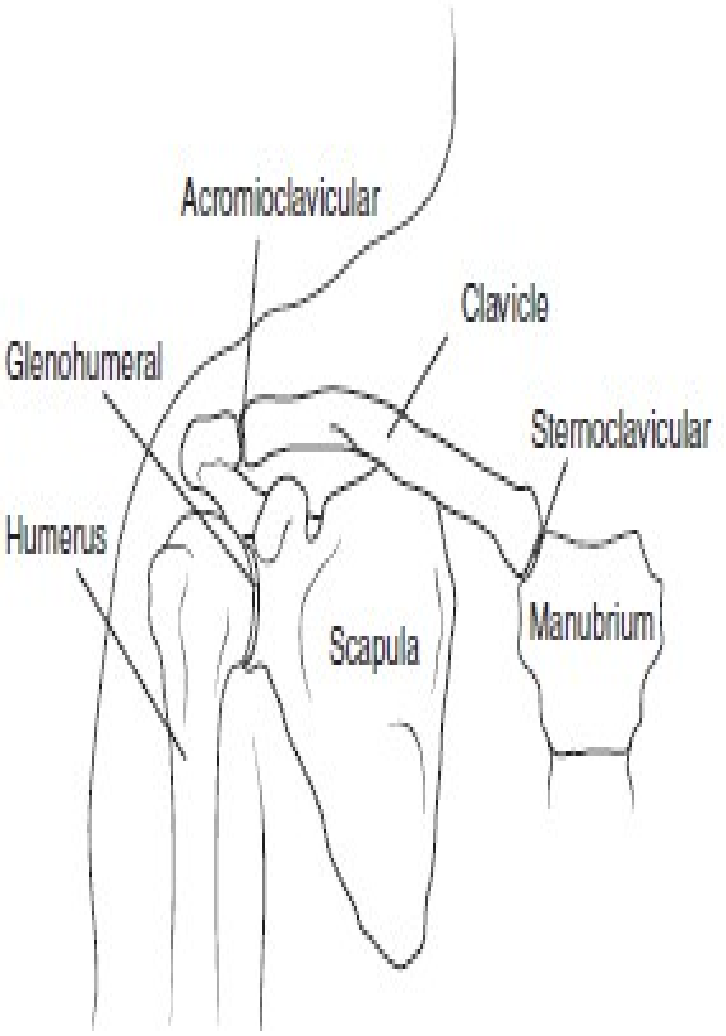
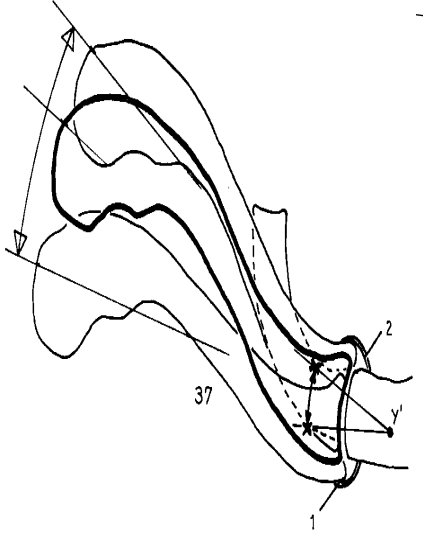


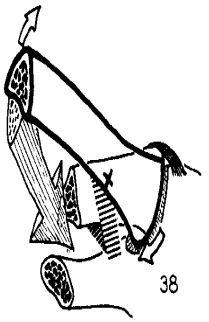
FIGURE 17.1 Bones and joints of the shoulder girdle complex.

Sternoclavicular Joint

Motions:



- **Protraction;** pect minor & major, seratus anterior..
- **Retraction** =rhombides minor, major & trapezious
- **Elevation;** levator scapulae & upper trapezious,



- **Depression**= pect minor & lower trapezious & subclavious, seratus anterior
- **Axial rotation (spin)**

Acromioclavicular Joint

- **Plane synovial joint** between the acromion process of the scapula and the distal clavicle.
  - allows limited motions in all three planes.
- Rotation occurs during arm elevation
- **Close-packed position** with humerus abducted to 90 degrees
- **In close- Packed position there is maximum contact between the articulating surfaces and stability is also maximum.**

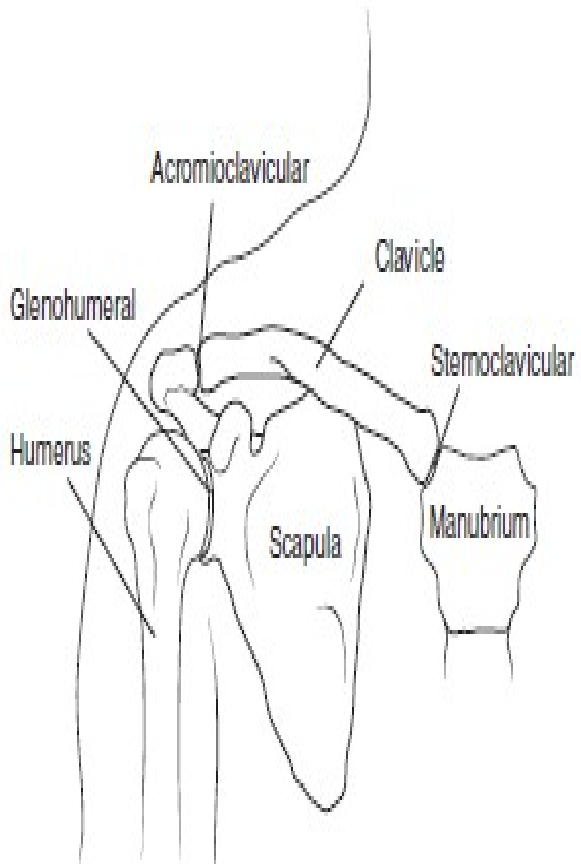
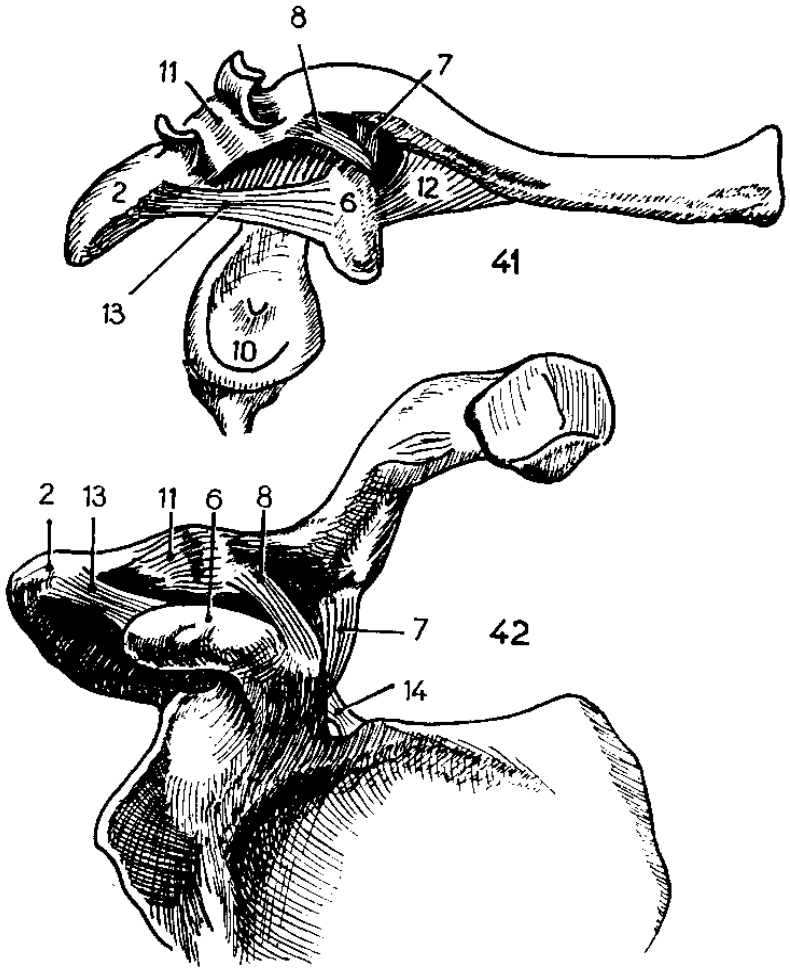


FIGURE 17.1 Bones and joints of the shoulder girdle complex.

Acromioclavicular Joint

Protected & stabalized by

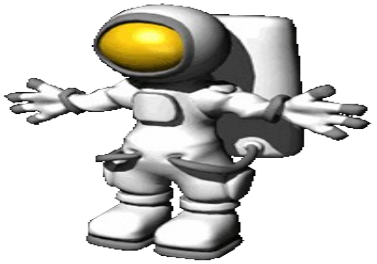
- Joint capsule
- A-C ligaments
- Intra-articular disc
- Coracoclavicular ligaments



Coracoclavicular Joint

- A syndesmosis with coracoid process of scapula
  - bound to the inferior clavicle by the Coracoclavicular ligament.
- Permits little movement

Glenohumeral Joint



- Most freely moving ball & socket joint in human body formed between head of humerus & glenoide cavity of scapula.
- **Stable by** : Glenoid Labrum (composed of fibrocartilage rim)& Joint capsul, Tendon of long head of biceps brachii
  - ❖Glenohumeral ligaments
  - ❖Rotator Cuff Muscles
- **Most stable in close-packed position,** when the humerus is abducted and laterally rotated.

Glenohumeral Motion

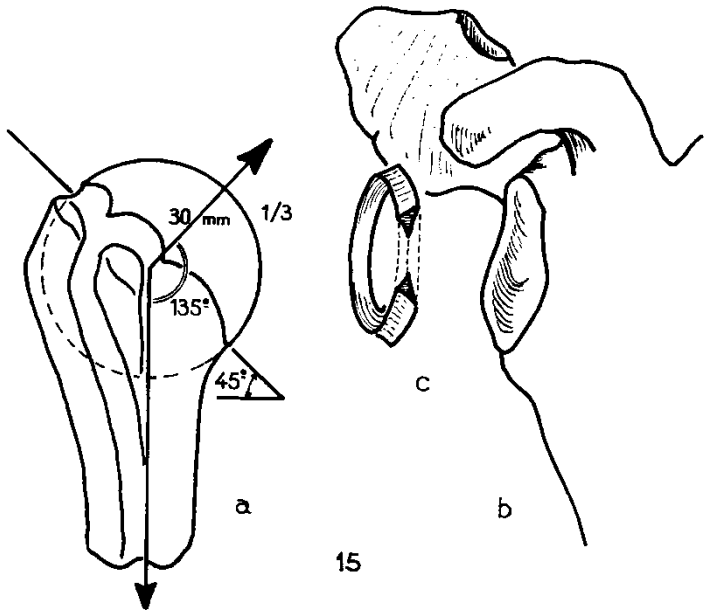
Controlled by:

- Passive restraints
- Active restraints

Glenohumeral Motion

Passive Restraints:

- Bony geometry
- Labrum
- **Capsuloligamentous structures**
- Negative intra-articular pressure



Capsuloligamentous Structures

- GH ligament and its capsule provide (ant, inf, posterior stability
- SGHL
- MGHL
- IGHL complex
  - anterior band
  - posterior band
  - axillary pouch

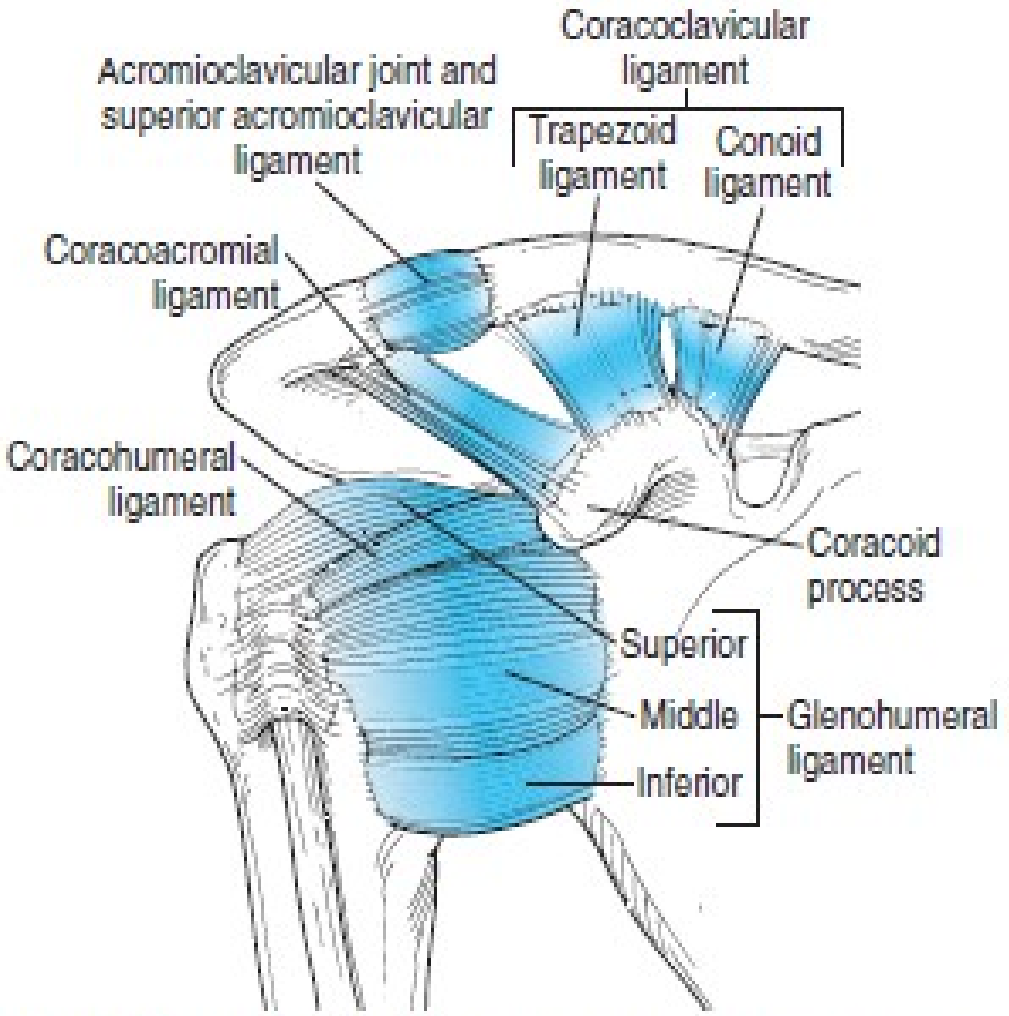


FIGURE 17.2 Ligaments of the glenohumeral and acromioclavicular joints.

- **At rest or dependent postion of shoulder joint:**
- SGHL and IGHL taut…, MGHL relax
- Adhesive and cohesive forces of synovial fluid and negative joint pressure hold surfaces together
- **When the humerus is elevating and scapula is rotating upward**
- **At 45 degree abduction and neutral rotation**= Tension placed on static restraints by the rotator cuff & middle gleno humeral(MGHL) ligament taut others relax (SGH, IGHL)
- **90 above abd & neutral rotation**= Tension placed on static restraints by the rotator cuff & IGHL taut & MGHL, SGHL relax.
- • Glenohumeral ligaments provide controlled inferior translation of humeral head

Active restrains:

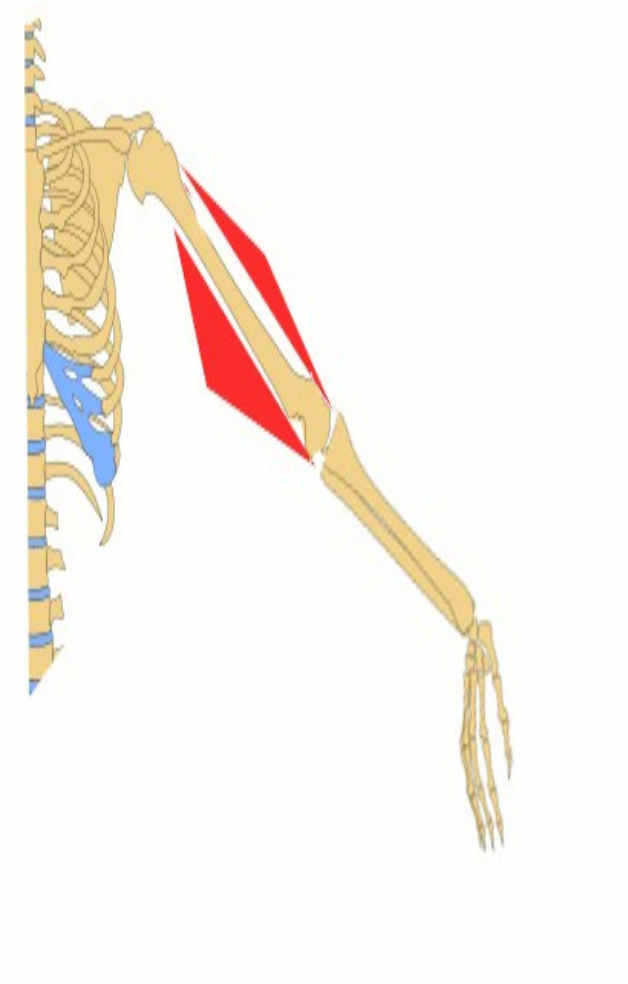
- Dynamic restraints
  - rotator cuff muscles (dynamic)
    - the primary biomechanical role of the rotator cuff is stabilizing the glenohumeral joint by compressing the humeral head against the glenoid
- **Biceps Long Head (dynamic)** acts as humeral head depressor as variable origin from superior labrum
- SGHL and subscapularis thought to play role in stabilizing long head of biceps

Scapulothoracic Joint

- Region between the anterior scapula and thoracic wall.
- Functions of muscles attach to scapula:
  - Contract to stabilize shoulder region
  - Stabilize scapula against chest wall
  - Facilitate movements through appropriate positioning of the Glenohumeral joint and scapula.

Movements of the Shoulder Complex

- Humerus movement usually involves some movement at all three shoulder joints to provide full range
- **Flexion:** anterior fibers of deltoid, coracobrachialis, pectoralis major, biceps brachii,
- **Extension:** latissimus dorsi and teres major, posterior fibers of the deltoid, long head of triceps,



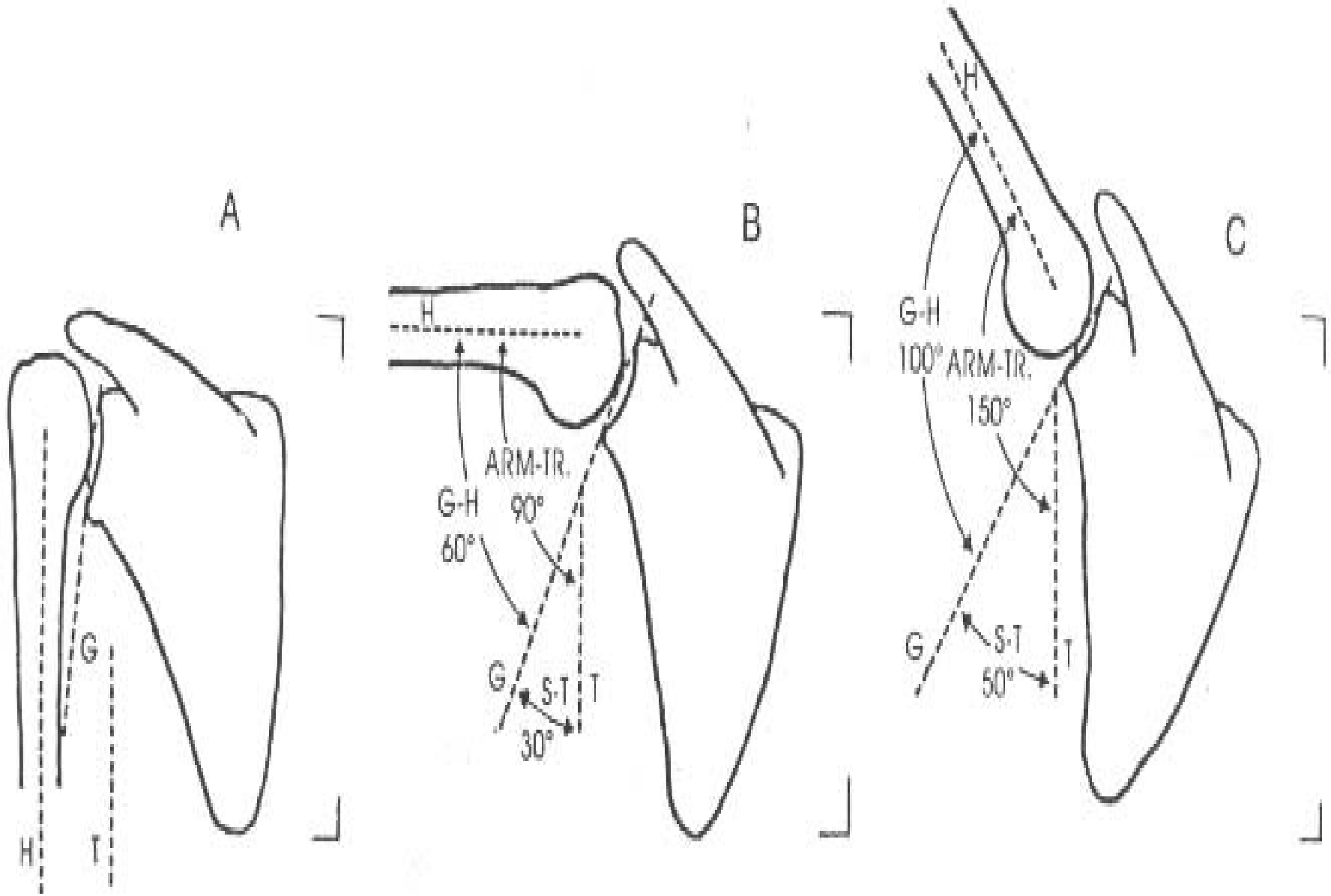
- **Abduction:** supraspinatus (first 15 degrees), deltoid; (scapula: Upward rotation) trapezius
- **Adduction:** (downward rotation of scapula) pectoralis minor, major, subclavius, latissimus dorsi, lower trapezius); **True Adduction**:, pectoralis major, subscapularis, teres major & minor, coracobrachialis, latissimus dorsi
- **Medial rotation:** subscapularis, latissimus dorsi,anterior fibers of deltoid,, pectoralis major,
- **Lateral rotation:** infraspinatus and teres minor, posterior fibers of deltoid
- **Positioning further facilitated by motions of spine**

Horizontal Adduction and Abduction at the Glenohumeral Joint

- HORIZONTAL ADDUCTION: Anterior to joint:
  - Pectoralis major (both heads), anterior deltoid, Coracobrachialis
  - Assisted by short head of biceps brachii
- HORIZONTAL ABDUCTION: Posterior to joint:
  - Middle and posterior deltoid, infraspinatus, teres minor
  - Assisted by teres major, Latissimus dorsi

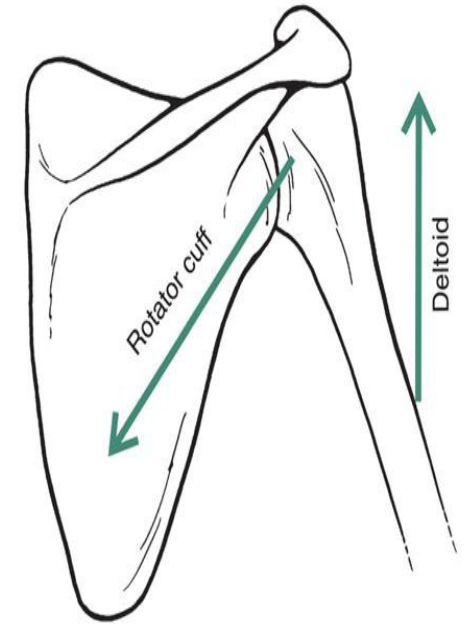
Scapulohumeral Rhythm

- It's a rhythm of movement b/w glenohumeral joint & scapula to complete full range of sh.joint.
- The ratio has considerable variation among individuals but is commonly accepted to be 2:1 (2 of glenohumeral motion to 1 of scapular rotation) overall motion.
- **During the setting phase** (0 to 30 abduction, 0 to 60 flexion), motion is primarily at the glenohumeral joint, whereas the scapula seeks a stable position.
- **During the mid-range** of humeral motion, the scapula has greater motion, approaching a 1:1 ratio with the humerus
- **later in the range**, the glenohumeral joint again dominates the motion


A
H
G
T
B
H
G-H
60°
ARM-TR.
90°
G
S-T
30°
T
C
H
G-H
100°
ARM-TR.
150°
G
S-T
50°
T

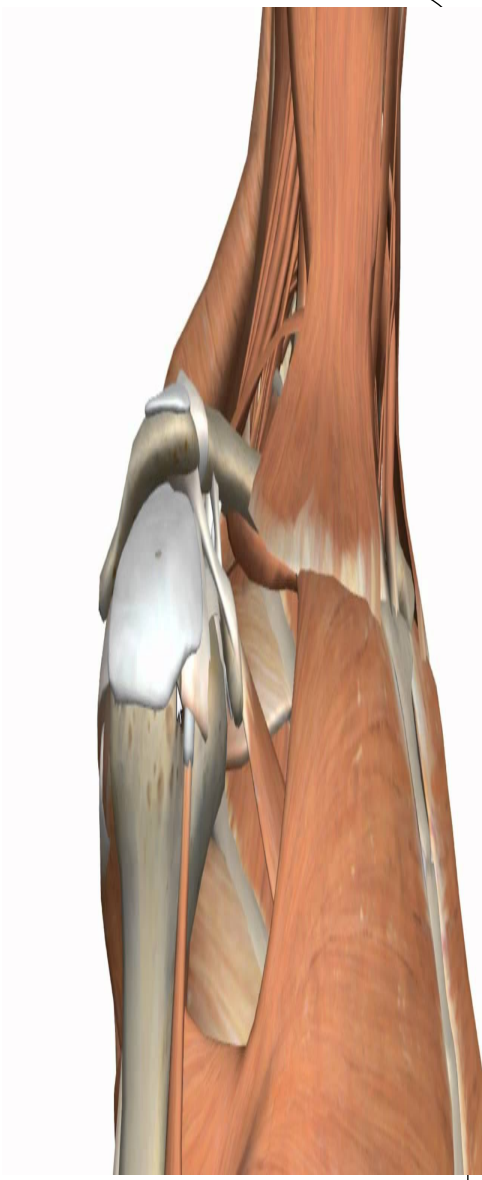
Loads on the Shoulder

- Shoulder joint bear most of the weight amongst all articulations of the shoulder girdle
- Shoulder has to provide direct mechanical support in daily activities provide tensile loading
- Large leverage, More compressive forces/tensile forces on the shoulder joint
- Deltoid produces upward **shear forces** as compared to rotator cuff which produces downward shear forces.



glenohumeral joint is considered to be a load-bearing joint.

- Although calculations the exact forces acting on it are challenging giving the large number of involved muscular and possible positions attainable,
- several simplifying assumptions allow an estimate of the magnitude of these forces.



- **Case A.** the arm is in 90° of abduction, and it is assumed that only the deltoid muscle is active. The force produced through BY deltoid muscle (D)acts at a distance of 3 cm from the center of rotation ,,. The force produced by the weight of the arm is estimated to be 0.05 times body weight (BW) and acts at a distance of 30 cm from the center of rotation.
- The reaction force on the glenohumeral joint (D) may be calculated with the use of the equilibrium equation that states that for a body to be in moment equilibrium must equal zero.

$M = 0$

$(30\ cm \times .05BW) - (D \times 3\ cm) = 0$

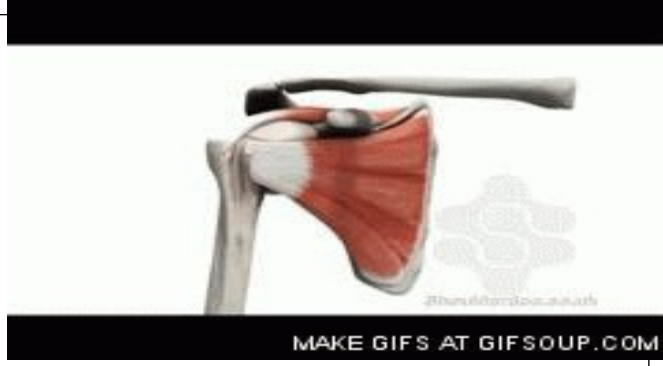
$D = 30\ cm \times .05\ BW \ / \ 3cm$

D= .5 BW

Because D and J are almost parallel but opposite. they form a force couple and are of equal magnitude; thus, the joint reaction force is also approximately one-half body weight!. (J=joint reaction forces)

- **Case B.** Similar calculations can be made to determine the value for D when a weight equal to 0.025 times body weight is held in the hand(60cm from center of rotation) with the arm in 90" of abduction with moment equilibrium must equal zero.
- M = 0
- (30 cm x .05BW) + (60 cm x .025 BW) - (D x 3 cm) = 0
- D = (30 cm x .05 BW) + (60 cm x .025 BW) **/3cm**
- **D= 1 BW**
- Once again. D and J are essentially equal and opposite. forming a force couple. Thus. the joint reaction force is approximately equal to body weigh

Loads on the Shoulder



- **Further loads quantity depend on Moment arm**:
  - Perpendicular distance between load vector and shoulder(axis) countered by moment arm.

A **moment arm** is simply the length between a joint axis and the line of force acting on that joint. Every joint that is involved in an exercise has a **moment arm**.

The longer the **moment arm** is; the more load will be applied to the joint axis through leverage.

- Large torques from extended moment arms countered by large no. of shoulder muscles
  - Load reduced by half with maximal elbow flexion

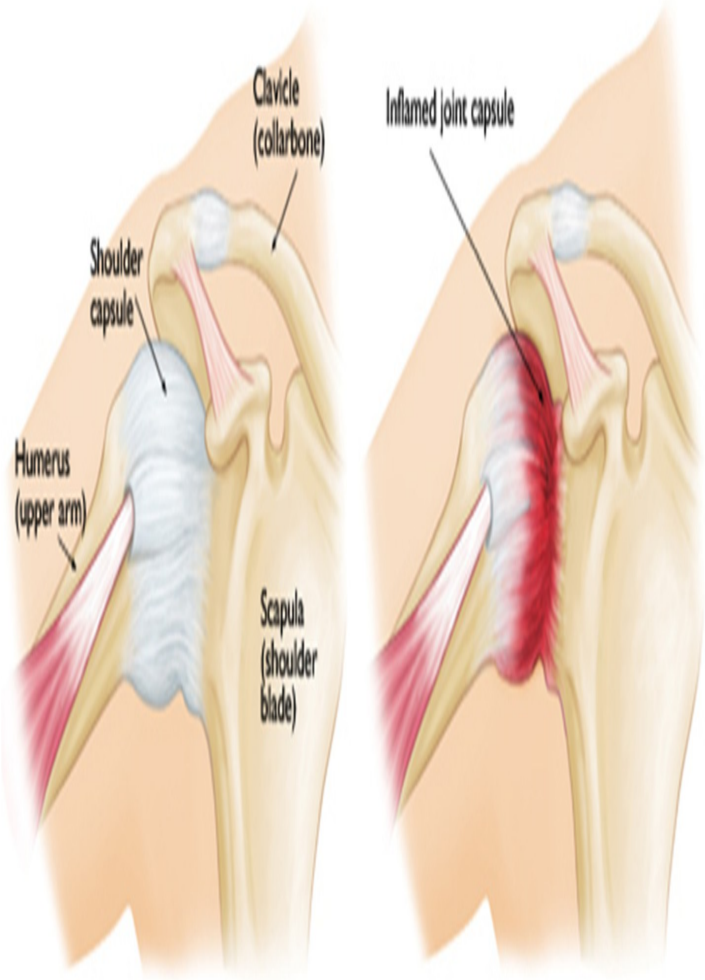
Common Shoulder Injuries

- Adhesive capsulitis
- Rotator Cuff Damage…….
  - Impingement Theory or syndrome…..
- Subscapular and suprascapular Neuropathy
- **Ectopic calcification**
  - Hardening of organic tissue through deposit of calcium salts in areas away from the normal sites
  - Dislocations

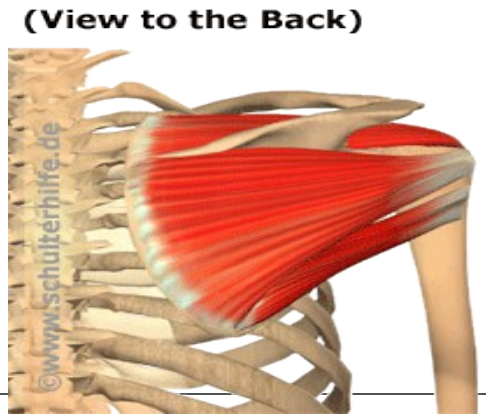
Frozen shoulder/adhesive capsulitis:

- **Restricted mobility of the glenohumeral joint *characterized* by the development of dense adhesions, capsular thickening, and capsular restrictions, especially in folds of the capsule, rather than arthritic changes in the cartilage and bone as a result of prolonged immobilization, or from unknown causes (idiopathic frozen shoulder)**

or may occur as a result of pathology such as osteoarthritis is called frozen shoulder



- **Impingement syndrome:**
- Mechanical compression and irritation of the soft tissues (rotator cuff/supraspinatous tendon and subacromial bursa) in the suprahumeral space is called *impingement syndrome* & is most common cause of shoulder pain.



Causes of impingement syndrome

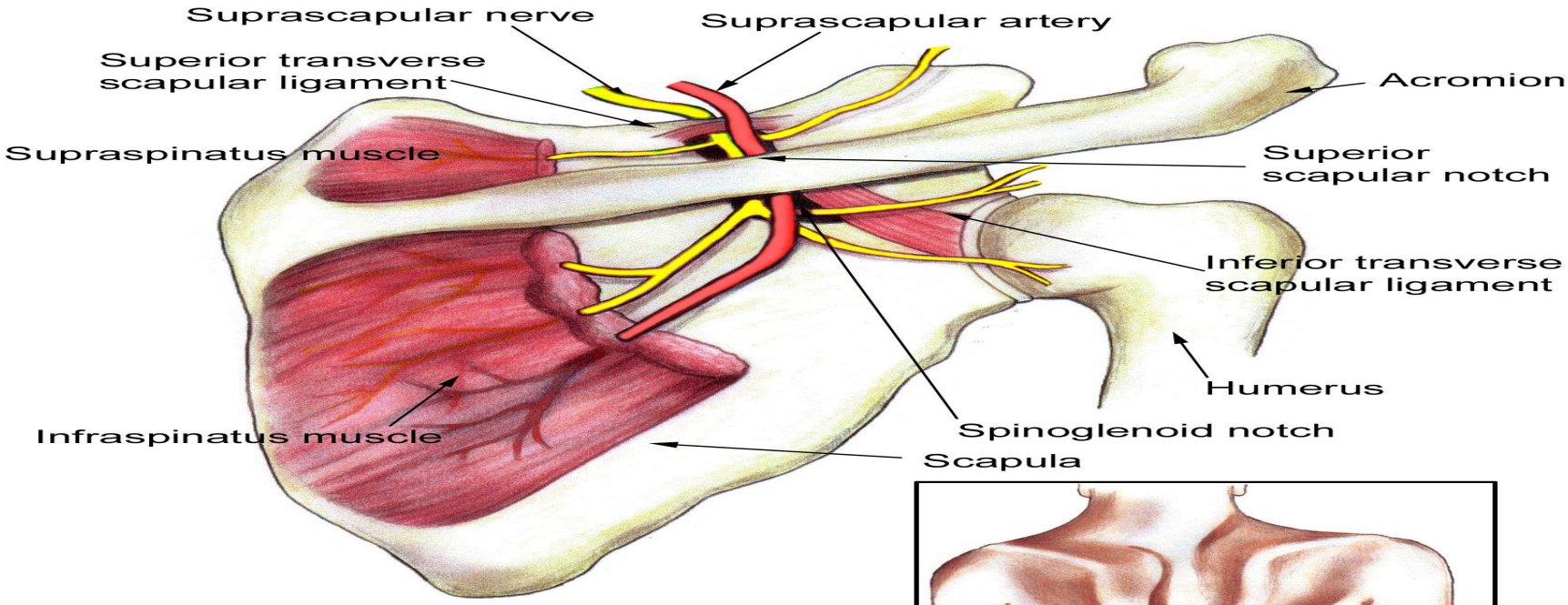
- When the arm is raised, the subacromial space narrows; the supraspinatus muscle tendon passes through this space.
- Anything that causes narrowing space has the tendency to impinge the tendon and cause an inflammatory response, resulting in impingement syndrome. Such causes can be bony structures such as subacromial spurs (bony projections from the acromion) and variations in the shape of the acromion(flat, hooked or curved)
- Loss of function of the rotator cuff muscles, due to injury or loss of strength, may cause the humerus to move superiorly, resulting in impingement. Inflammation subacromial bursa may also cause impingement

Supracapular Neuropathy

- patient is a young overhead athlete who reports posterior shoulder pain.
- Although, athlete can have painless atrophy presenting as supraspinatus and/or infraspinatus weakness, depending on the location of the suprascapular nerve lesion.
- More distal nerve injuries are often relatively painless.

In particular, injuries at the spinoglenoid notch that result in selective denervation of the infraspinatus muscle may be painless condition..

more proximal lesions of the suprascapular nerve that affect both the supraspinatus and infraspinatus muscles are more likely to have pain and symptom-limited function.



Subscapular neuropathy

- **upper subscapular nerve (short subscapular),** enters the upper part of the Subscapularis
- The **lower subscapular nerve** (**inferior subscapular nerve**) is a nerve that supplies the lower part of the **subscapularis muscle**, and also to **teres major** muscle.

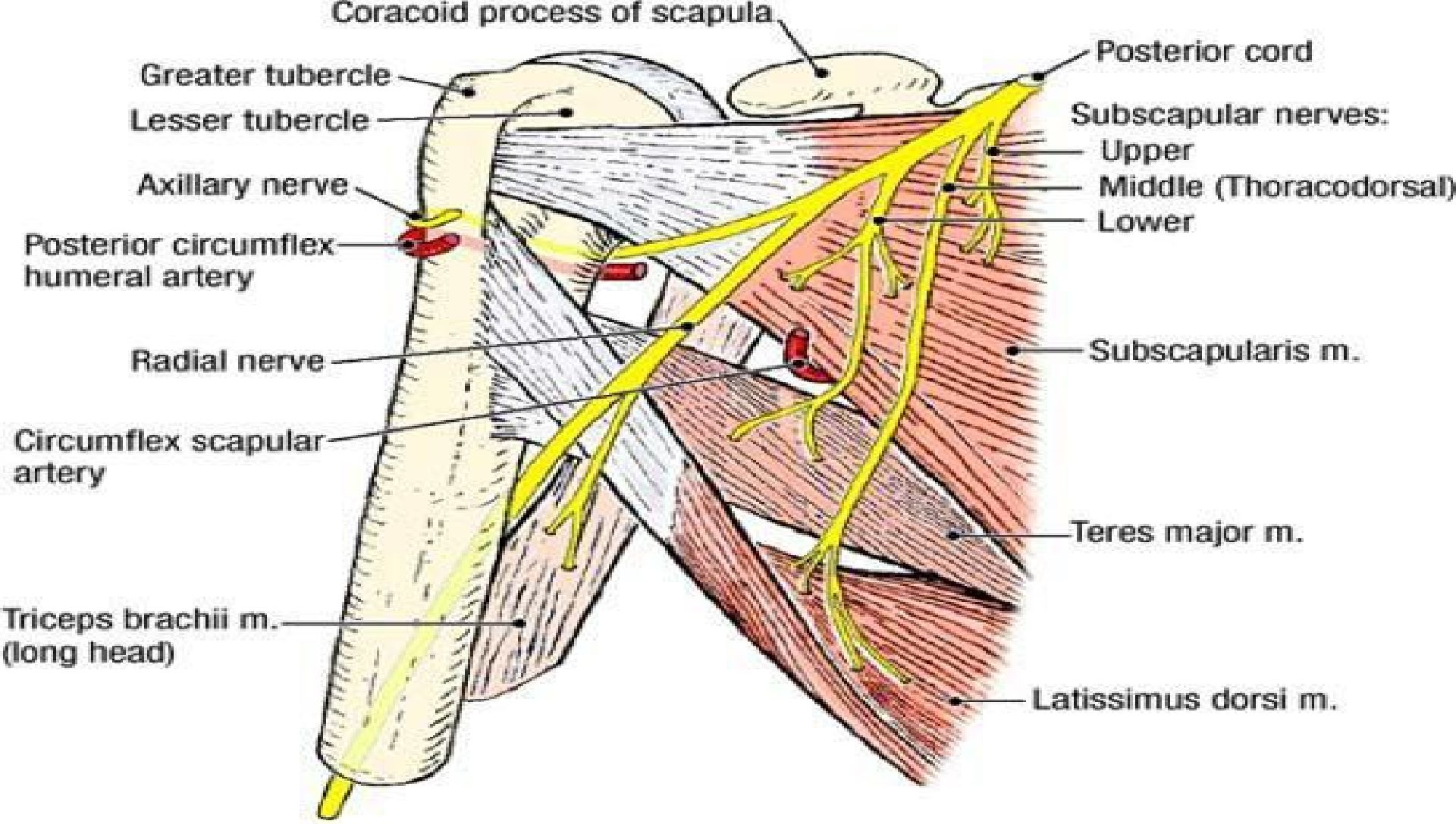
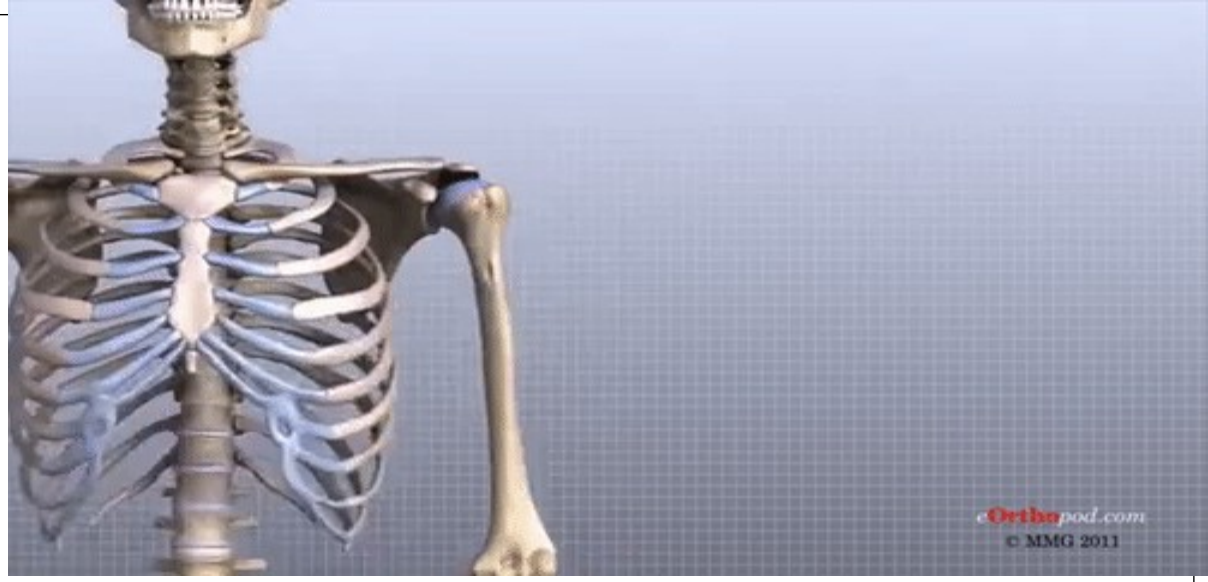


Figure 2.13. Posterior wall of the axilla and posterior cord of the brachial plexus.

- The subscapularis rotates the head of the humerus medially (internal rotation); **medial rotation mean** when the arm is raised, it draws the humerus head inward and downward.
- It is a powerful defense to the front of the shoulder-joint, preventing displacement of the head of the humerus.
- **Subscapular neuropathy results in:-**
- **Weak medial rotation of shoulder joint and decrease stability of shoulder joint**

Dislocations

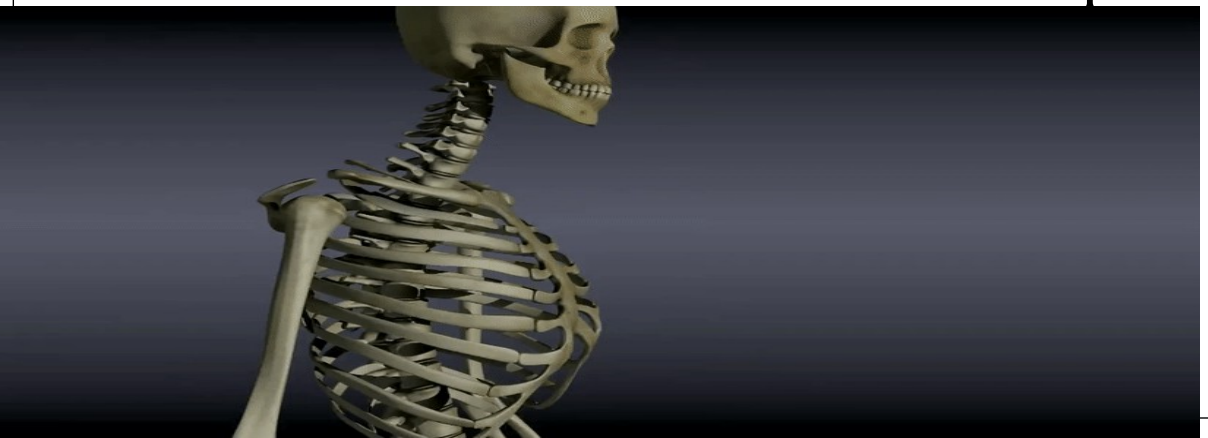


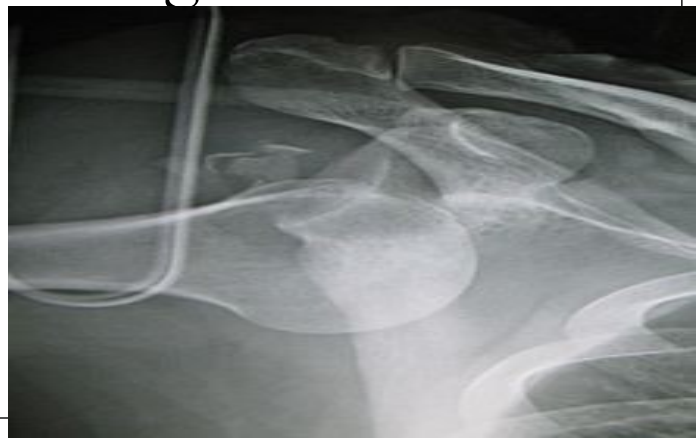
- Loose structure of shoulder leads to extreme mobility = less stability
- It may be Posterior, Anterior or inferior dislocation
- Occurs mostly in Contact sports due to Glenohumeral capsular laxity &weakness of shoulder musculature

anterior shoulder dislocation.

. The mechanism of injury is usually occure when anterio-posterior force applied to the arm when it ispositioned in flexion, adduction, and internal rotation, such as falling on an outstretched arm.

- In that position, stability is provided by the subscapularis, GH ligaments and long head of the biceps. A significant force to the arm may damage these structures, along with the attachment of the anterior capsule and glenoid labrum.



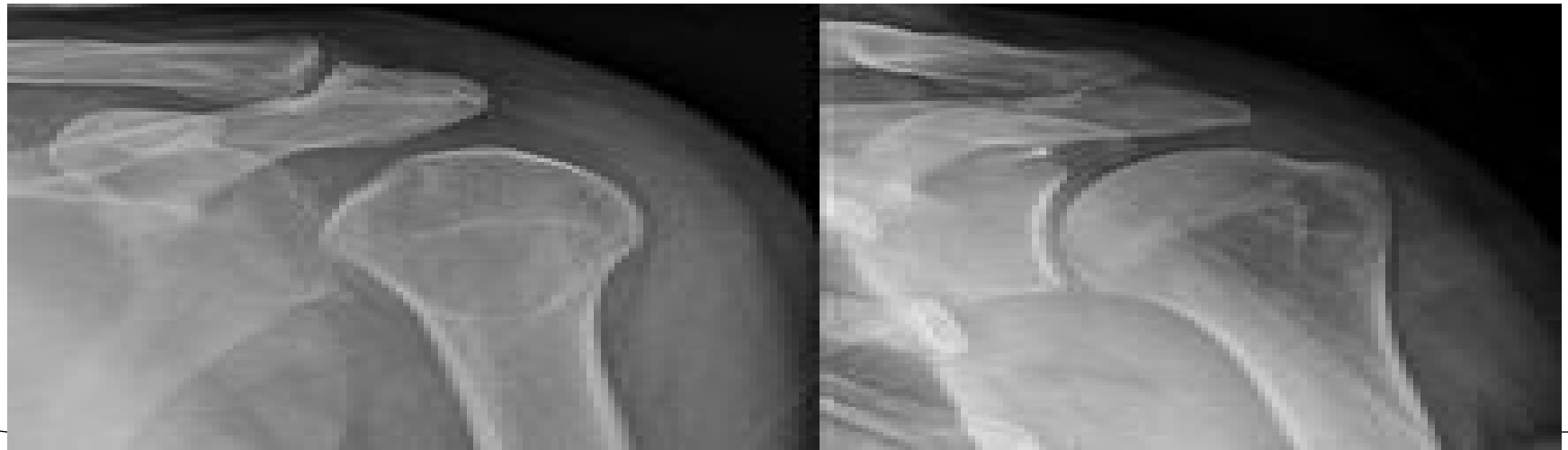


Posterior dislocation

- Traumatic posterior shoulder dislocation is less common.

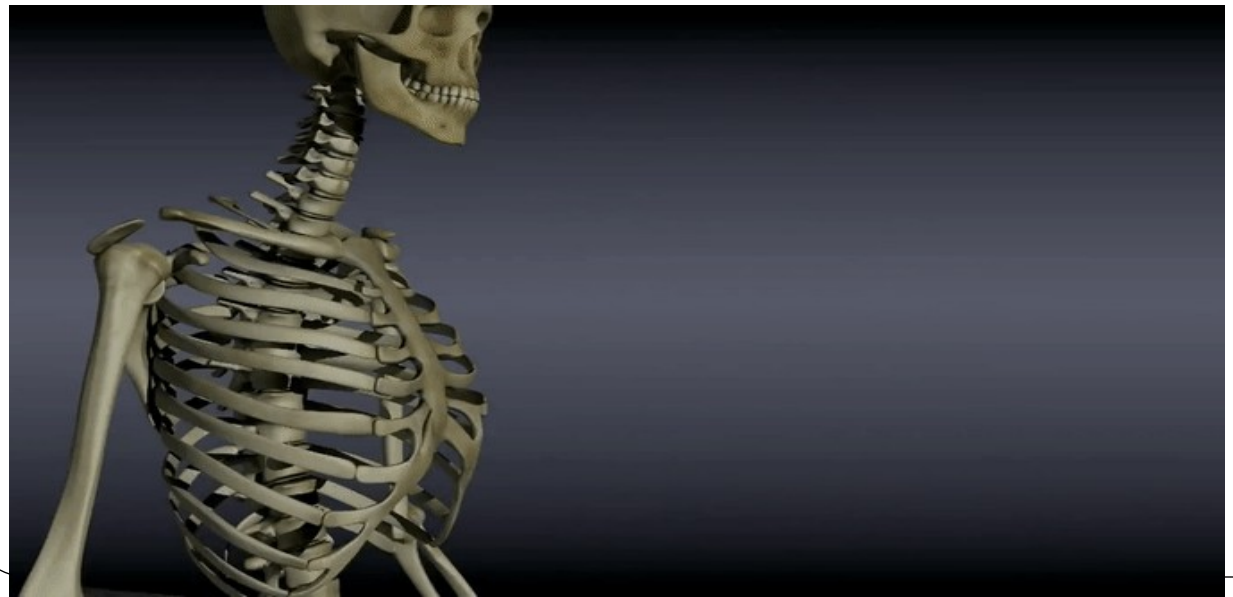
Posterior dislocation most frequently occurs when there is posteriorly directed anterior force act the arm while the humerus is in a position of elevation, external rotation, and abduction.

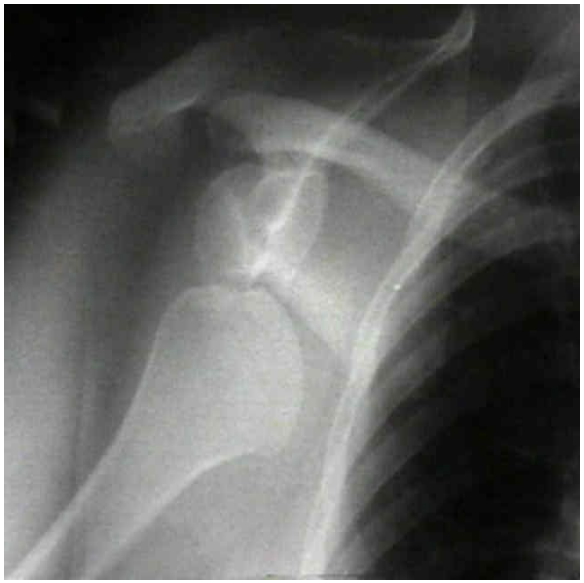
- The person complains of symptoms when doing activities such as push-ups, a bench press.

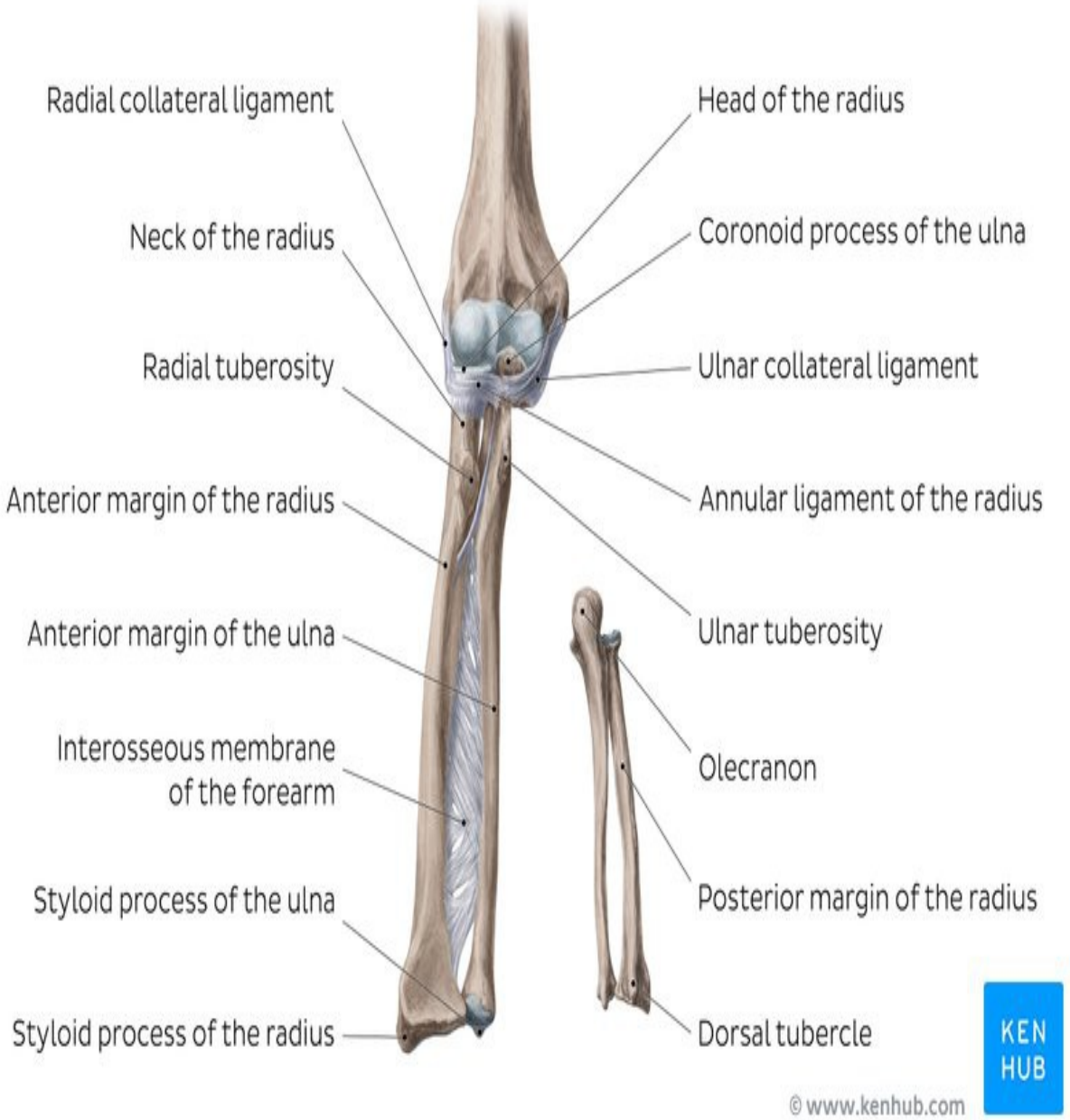


Inferior dislocation

- Inferior dislocation occurs as a result of inferior instability is typically the result of rotator cuff weakness/paralysis and is frequently seen in patients with hemiplegia.
- It is also prevalent in patients who repetitively reach overhead (workers or swimmers, for example) and those with multidirectional instability.






Radial collateral ligament
Neck of the radius
Radial tuberosity
Anterior margin of the radius
Anterior margin of the ulna
Interosseous membrane of the forearm
Styloid process of the ulna
Styloid process of the radius
Head of the radius
Coronoid process of the ulna
Ulnar collateral ligament
Annular ligament of the radius
Ulnar tuberosity
Olecranon
Posterior margin of the radius
Dorsal tubercle
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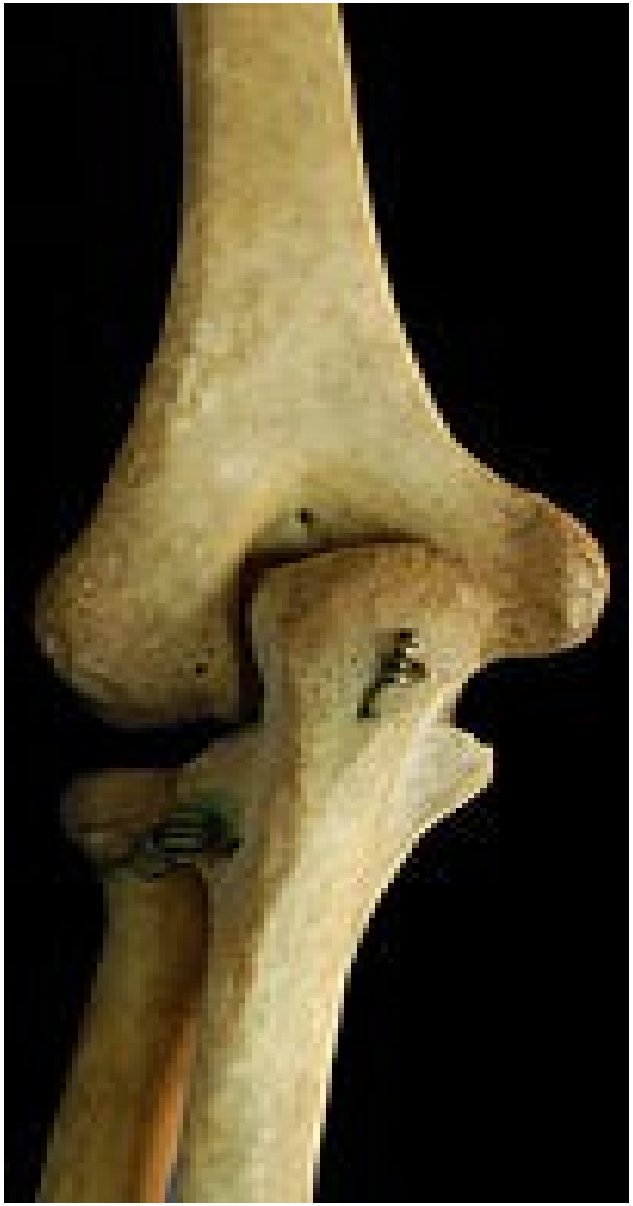
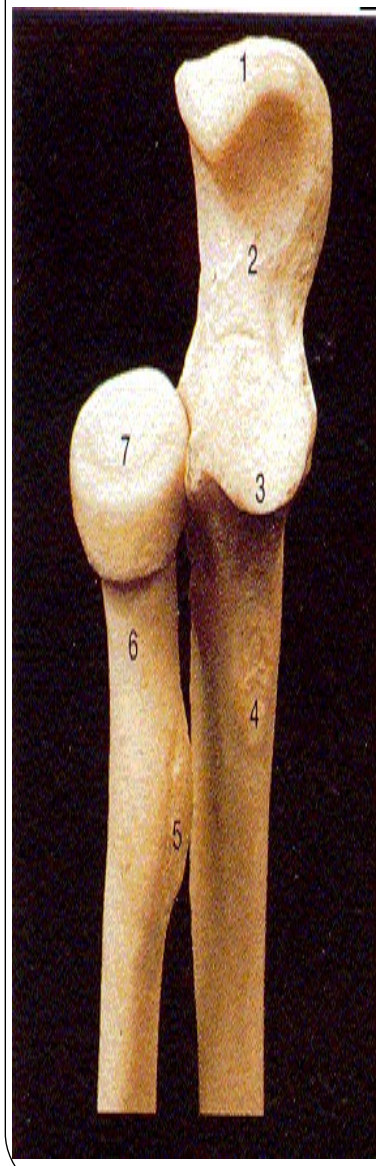


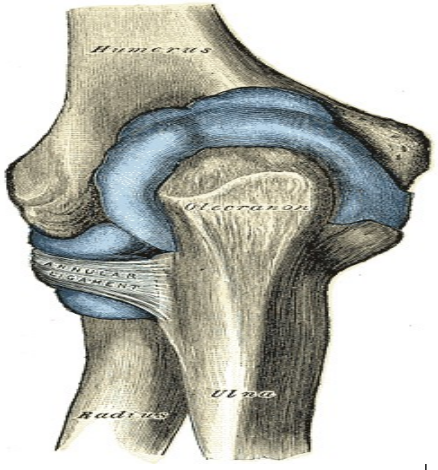
Elbow Articulations



- The **elbow** is the visible joint between the upper and lower parts of the arm.
- It includes prominent landmarks such as the **olecranon**, the elbow pit, the lateral and **medial epicondyles**, and the **elbow joint**.
- **Humeroulnar Joint**
- A true elbow joint is the synovial hinge joint , between **trochlear notch** of the ulna & trochlea of humerus allows movement of flexion & extension only.

- **Humeroradial Joint formed b/w Radius Head & Capitulum of humerus ,** Slides along capitulum in Flex & Ext. Modified ball and socket joint but Provides no ABD or ADD
- **Proximal Radioulnar Joint b/w head of radius & radial notch on ulna; bounded by** Annular ligament
  - In any position of flexion or extension, the radius, carrying the hand with it, can be rotated in it.
  - This movement includes pronation and supination.

Elbow joint



- **Capsule**: Anterior, Posterior, Medial, Lateral
- Large, loose and weak
- Reinforced by other ligaments. MCL & LCL
- **The synovial membrane** of elbow joint is very extensive. On the humerus, **it extends up** from the articular margins and covers **coronoid** and **radial fossa** anteriorly and the **olecranon fossa** posteriorly.
- **Distally**, it is prolonged down to the neck of the radius and superior radioulnar joint. It is supported by the quadrate ligament below the annular ligament where it also forms a fold which gives the head of the radius freedom of movement
- **Close pack position: extension**

- Functions as a fulcrum for forearm lever
- In patients using crutches, it functions as a weight bearing joint.
- During throwing activities, there is transfer of energy between the shoulder and elbow, crucial for activities of daily living

- **Flexion ;**
- the biceps brachii and the brachialis **muscles** are the main flexors of the **elbow joint**, and brachioradialis **muscle** is also involved.
- **Extension -** triceps brachii muscle with a negligible assistance from anconeus.
- **Pronation**…;The **pronator teres** is a muscle (located mainly in the forearm) that, along with the **pronator quadratus**, serves to pronate the forearm (palm faces posteriorly)
- **Supination** ;
- The **supinator** is a broad **muscle** in the posterior compartment of the **forearm**, curved around the upper third of the radius. Its function is to **supinate** the **forearm**.

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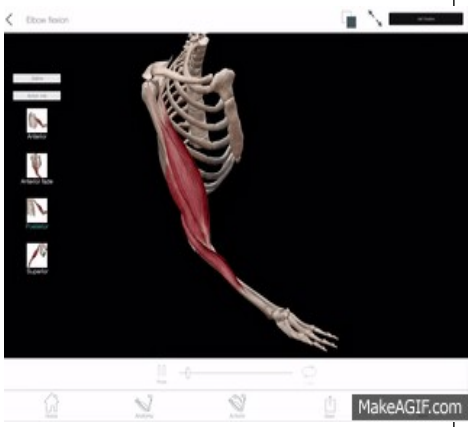
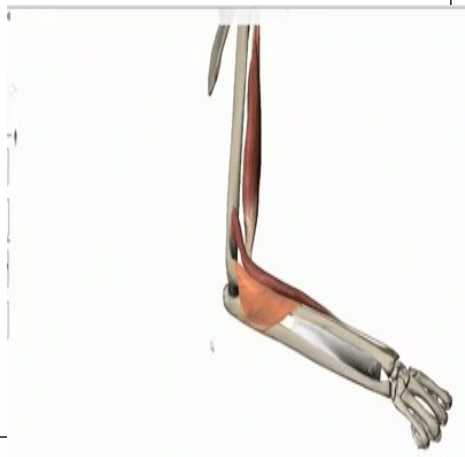


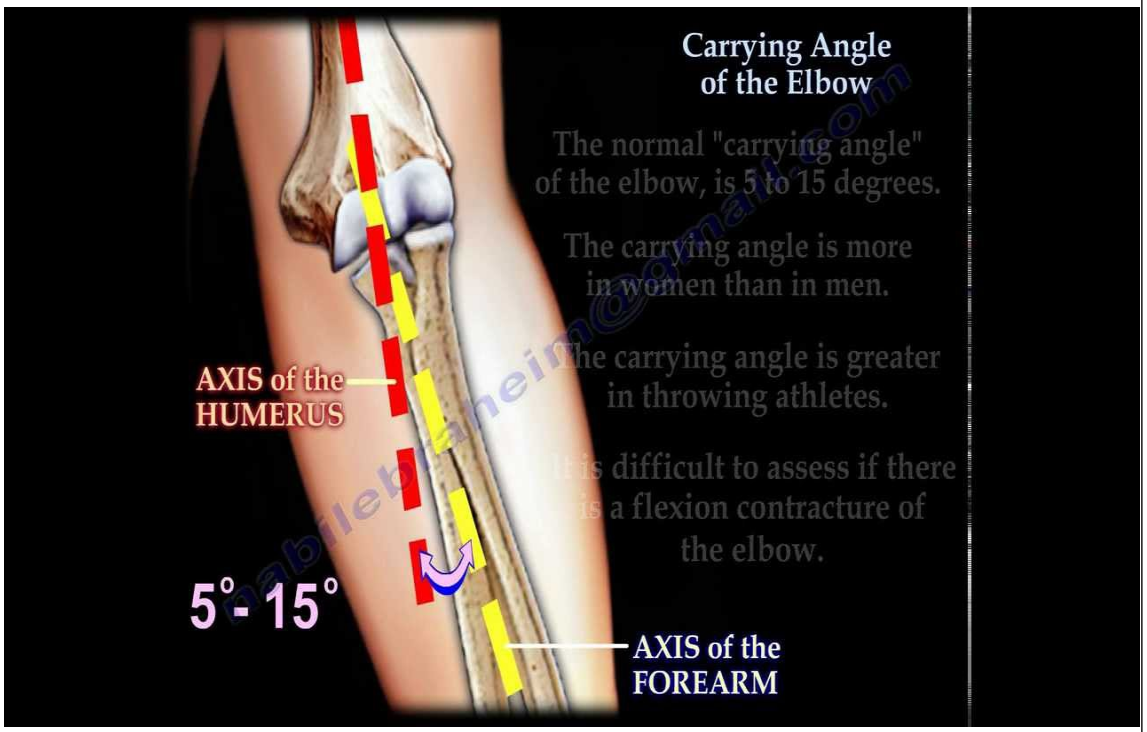


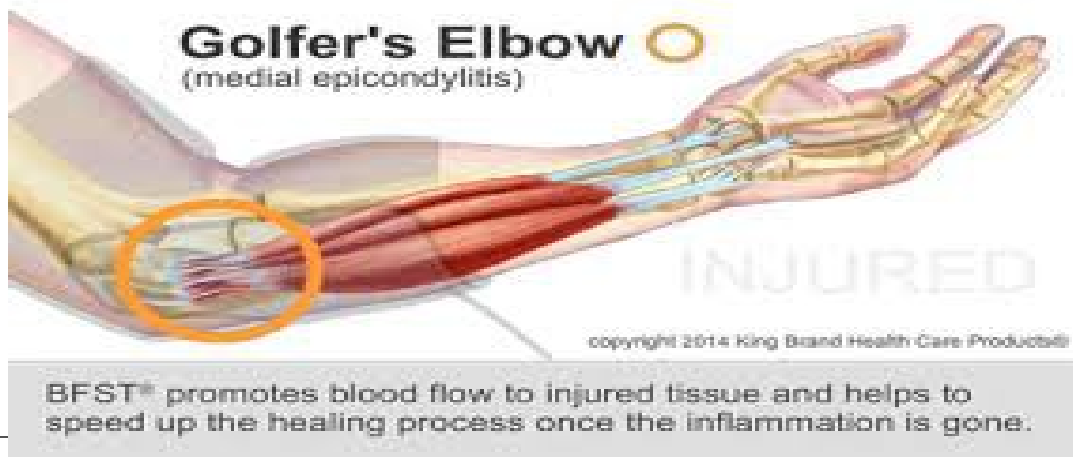
Loads on the Elbow

- Large loads generate by muscles that cross elbow during forceful activities, Also in weight lifting, gymnastics, other sports
- Extensor moment arm shorter than flexor moment arm. there are large joint reaction forces due to short and inefficient lever arms around elbow (biceps inserts not far from center of rotation) this contributes to degenerative changes of the elbow
- Triceps attachment to ulna closer to elbow joint center than brachialis on ulna and biceps on radius (not far from center of rotation) source of more degeneration.
- **(ecentric loading=more degeneration as compare to concentric loading)**
- Moment arm varies with position of elbow e.g. **Axial loading extended elbow** , 40% of weight is through HU joint, 60% of weight is through HR joint

Common injuries>

- Tennis elbow
- Golfers elbow
- Fractures
- Unlar nerve entrapment syndrome
- Cubitus valgus & varus deformity



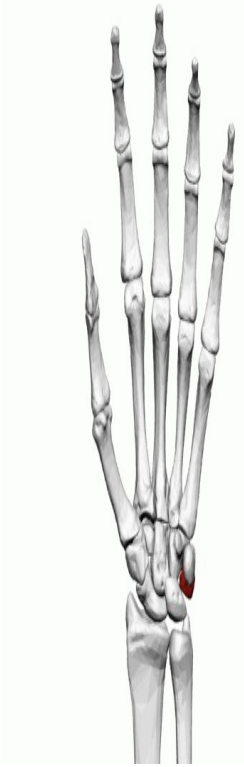


Unlar nerve entrapment syndrome

- At the elbow, the ulnar nerve travels through a tunnel of tissue (the cubital tunnel) that runs under medial epicondyle. The spot where the nerve runs under the medial epicondyle is close to your skin, and bumping it causes a shock-like feeling **or** the most common place for compression of nerve is called "cubital tunnel syndrome."
- Numbness and tingling in medial one & half hand and fingers are common symptoms of cubital tunnel syndrome associated with muscle weakness.
- Beyond the elbow, the ulnar nerve travels under muscles on the inside of your forearm and into your hand on the side of palm with little finger. As the nerve enters the hand, it travels through another tunnel (Guyon's canal, another site for compression of nerve but not common site)

THE WRIST JOINT

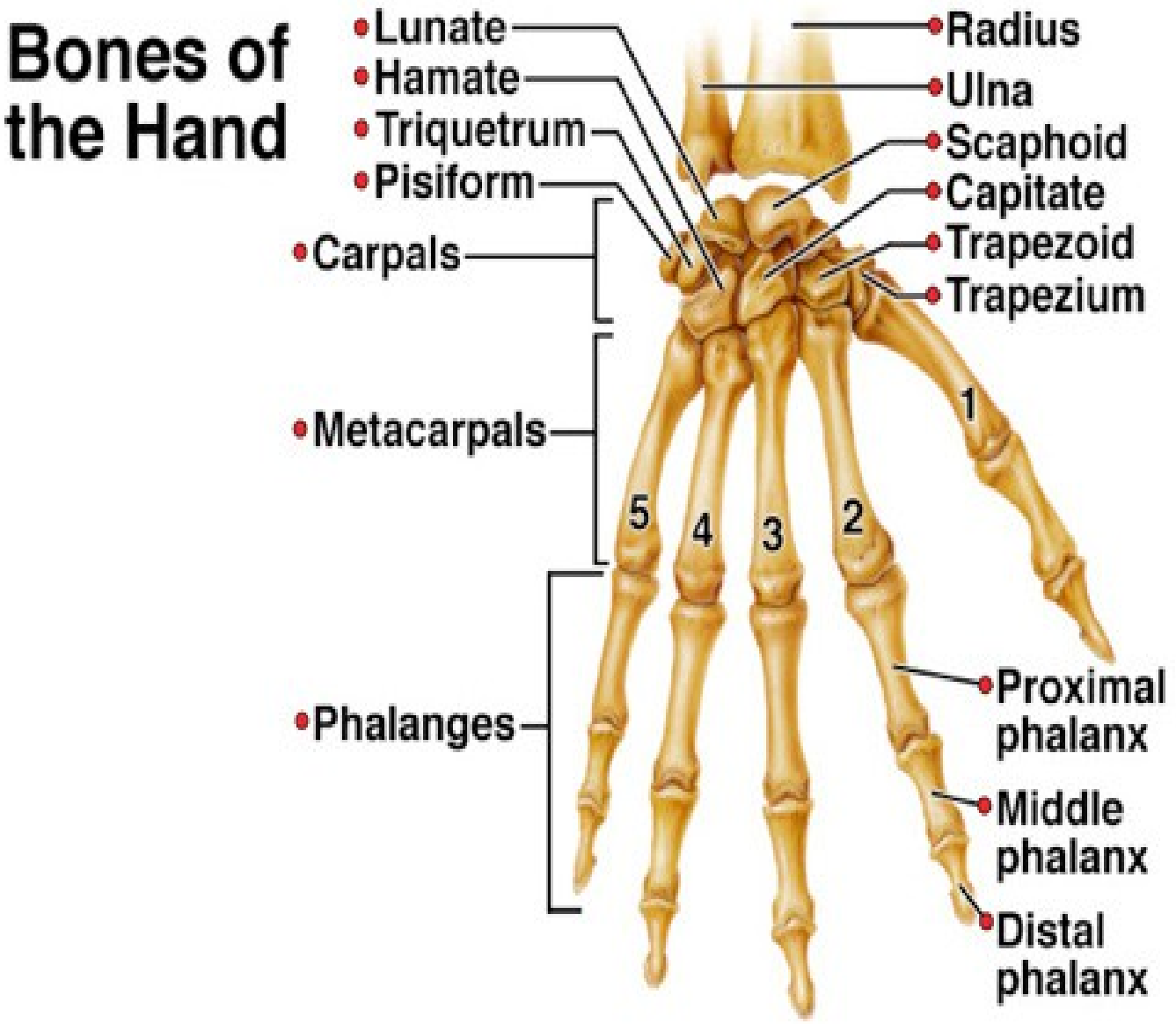
- A biaxial, ellipsoid-type **joint** that serves as the articulation between the distal end of the radius above and carpals (the scaphoid, lunate, and triquetral bones) below.
  The **joint's** primary role is to optimize hand function.
- Sagittal and frontal plane movements and Rotary motion in transvers plane



- **Extension:** extensor carpi radialis longus, extensor carpi radialis brevis, extensor carpi ulnaris,extensor digitorum,
- **Palmar flexion**: flexor carpi ulnaris, flexor carpi radialis, flexor digitorum superficialis, flexor digitorum profundus,
- **Radial abduction:** extensor carpi radialis longus, , flexor carpi radialis, flexor, abductor and extensor pollicis longus
- **Ulnar adduction:** extensor carpi ulnaris, flexor carpi ulnaris, extensor digiti minimi

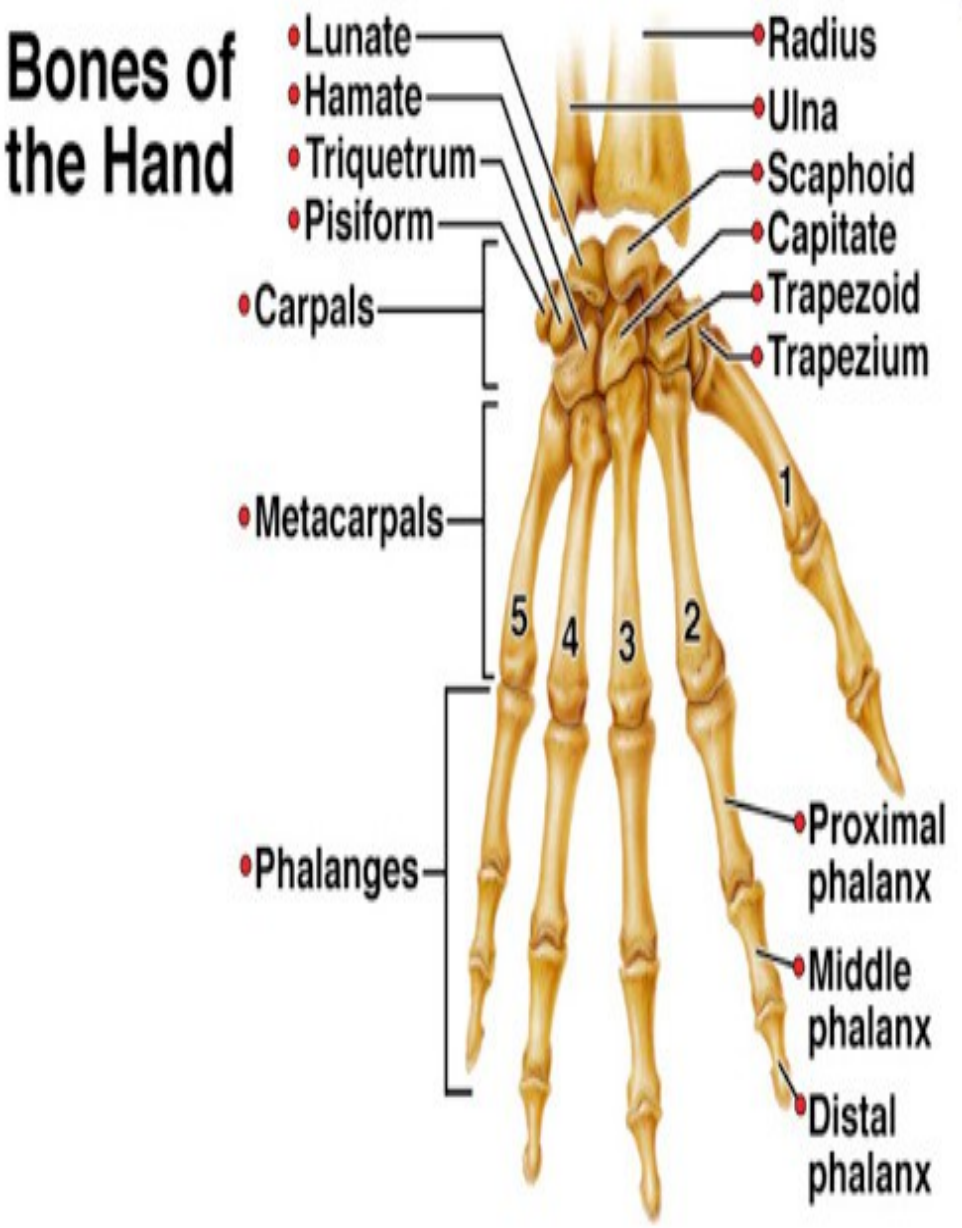
Wrist and Hand Bones

- Scaphoid
- Lunate
- Triquetrium
- Pisiform
- Trapezium
- Trapezoid
- Capitate
- Hamate



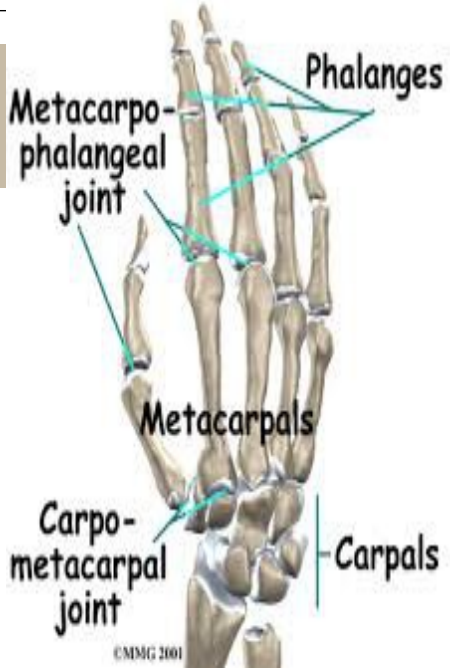
Wrist and Hand Bones

- Hand
  - Metacarpals
  - Phalanges 2-5
    - Proximal
    - Middle
    - Distal
  - Phalange 1 (Thumb)
    - Proximal &Distal
- Carpometacarpal (CM)
- Metacarpophalangeal (MP)
- Interphalangeal (IP)



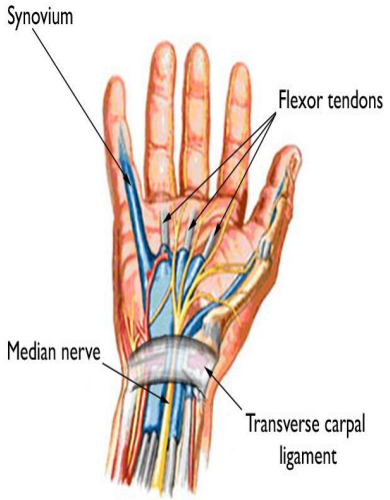
Movement Of Hand

- The numerous bones, joints, and muscles in the **hand** produce several **movements** — flexion, extension, abduction, adduction, opposition, and reposition
- Stability is provided by numerous ligaments: the ulnar and radial collateral, the dorsal and volar (palmar) radiocarpal, the ulnocarpal, and the intercarpal.



Common Injuries of the Wrist and Hand

- **Wrist pain** has a number of causes, including carpal tunnel syndrome, ganglial cyst, and osteoarthritis.
- The hand may be deviated at the wrist in some conditions, such as rheumatoid arthritis.
- Ossification of the bones around the wrist is one indicator used in taking a bone age.
- The term 'wrist fracture' may be used to refer to fractures of the distal radius.

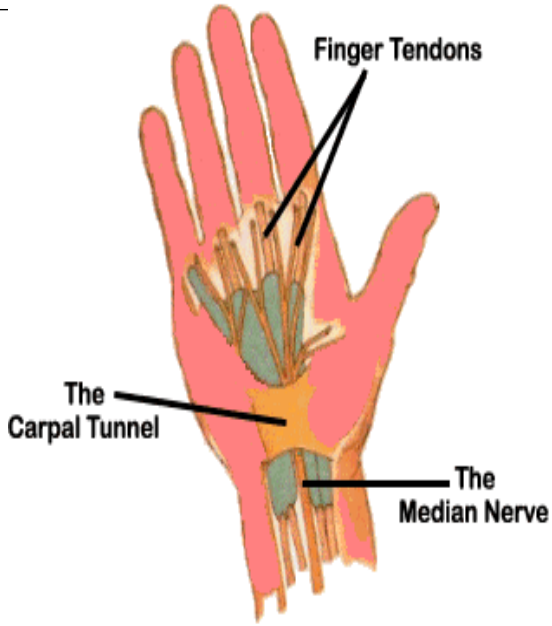


Common Injuries of the Wrist and Hand

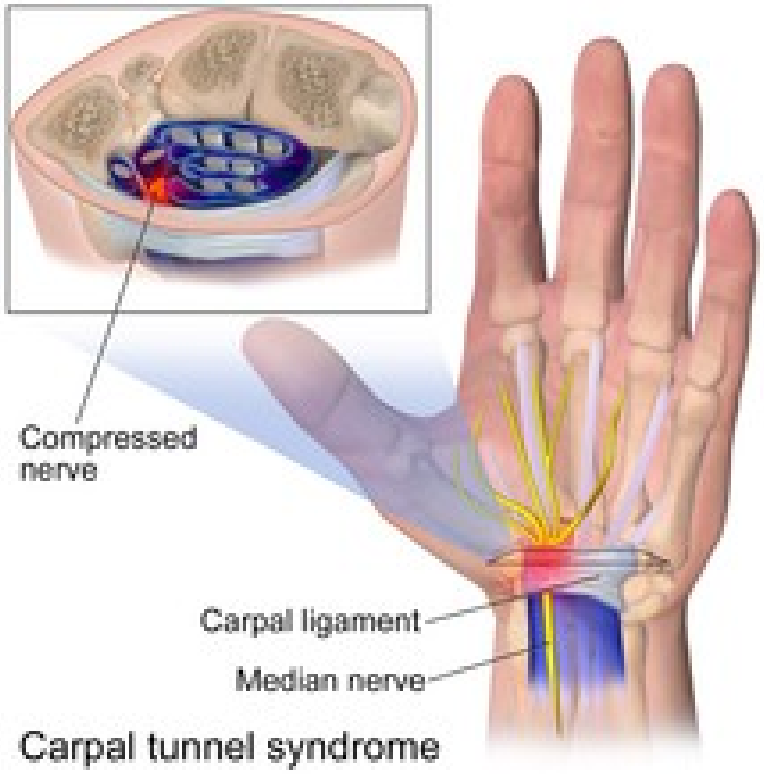
- Sprains and strains rare, but occur due to a fall on hyperextended wrist
- **Certain injuries characteristic of sport type**
  - Metacarpal fractures (frequent seen in **football)**
  - Ulnar collateral ligament (hockey)
  - Wrist fracture (skate/snowboarding
  - Wrist injuries in non-dominant hand for golfers
- **Carpal Tunnel Syndrome**

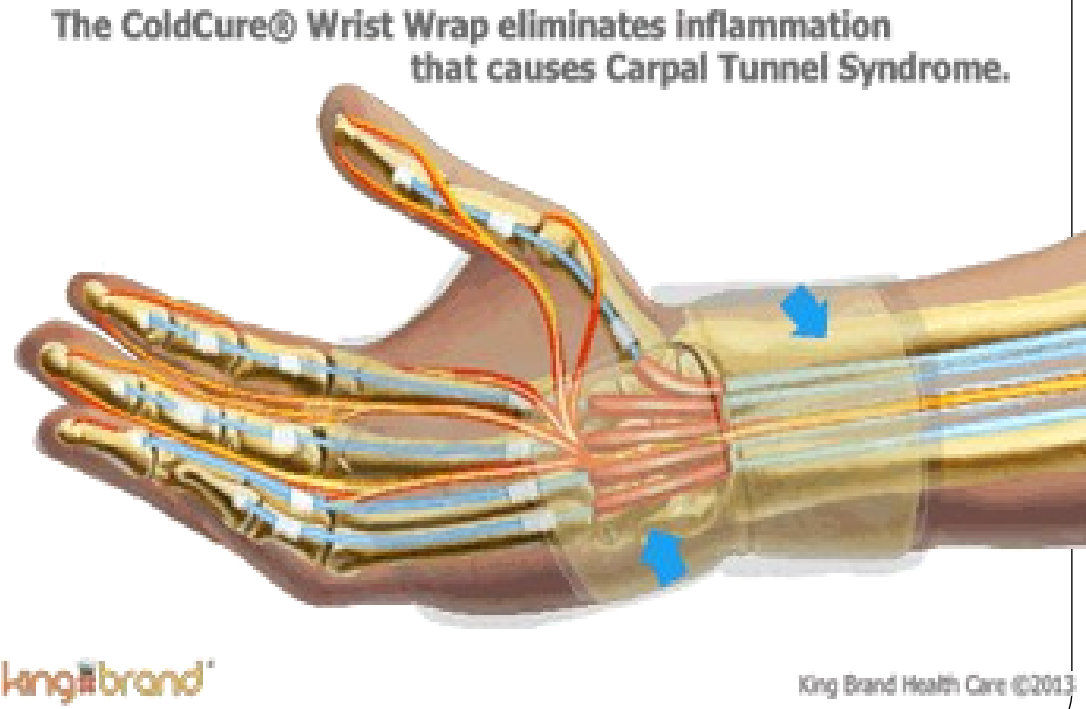
Carpal Tunnel

- In the human body, the **carpal tunnel** or **carpal canal** is the passageway on the palmar side of the wrist that connects the forearm to the hand.
- The tunnel is bounded by the bones of the wrist and flexor retinaculum from connective tissue. Normally several tendons from the flexor group of and the median nerve pass through it.
- The canal is narrow, and when any of the nine long flexor tendons passing through it swell or degenerate, the narrowing of the canal may result in the median nerve becoming entrapped or compressed, a common medical condition known as carpal tunnel syndrome

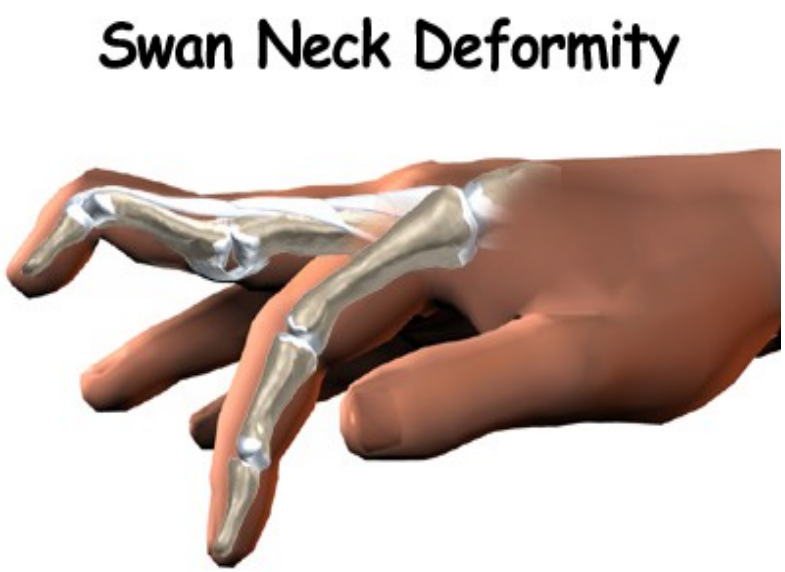


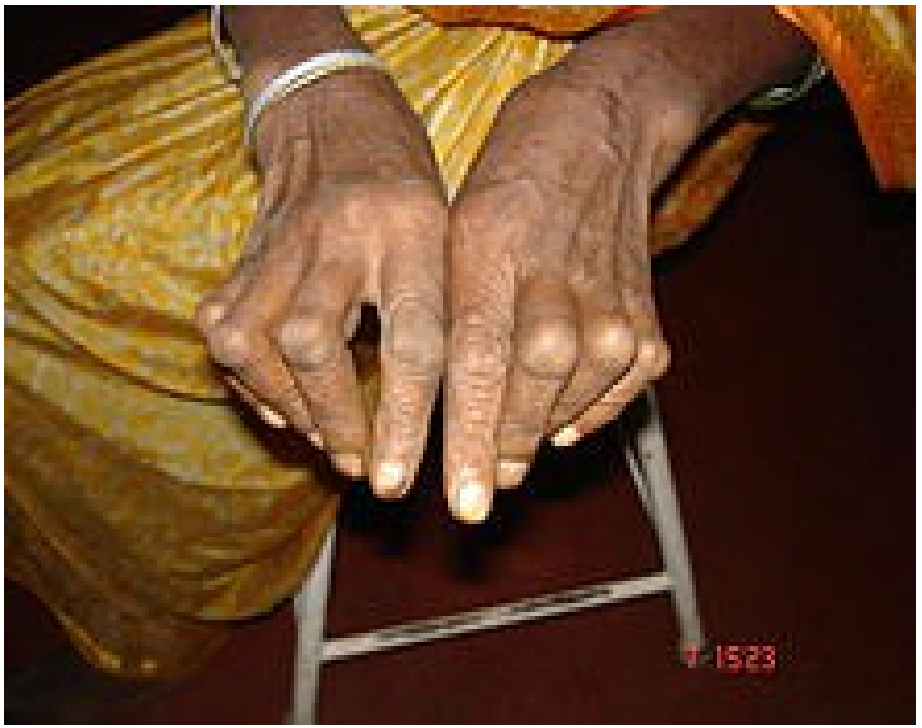
- **Carpal tunnel** syndrome (CTS) is a medical condition due to compression of the median nerve as it travels through the wrist at the **carpal tunnel**. The main symptoms are pain, numbness and tingling in the thumb, index finger, middle finger and the thumb side of the ring fingers





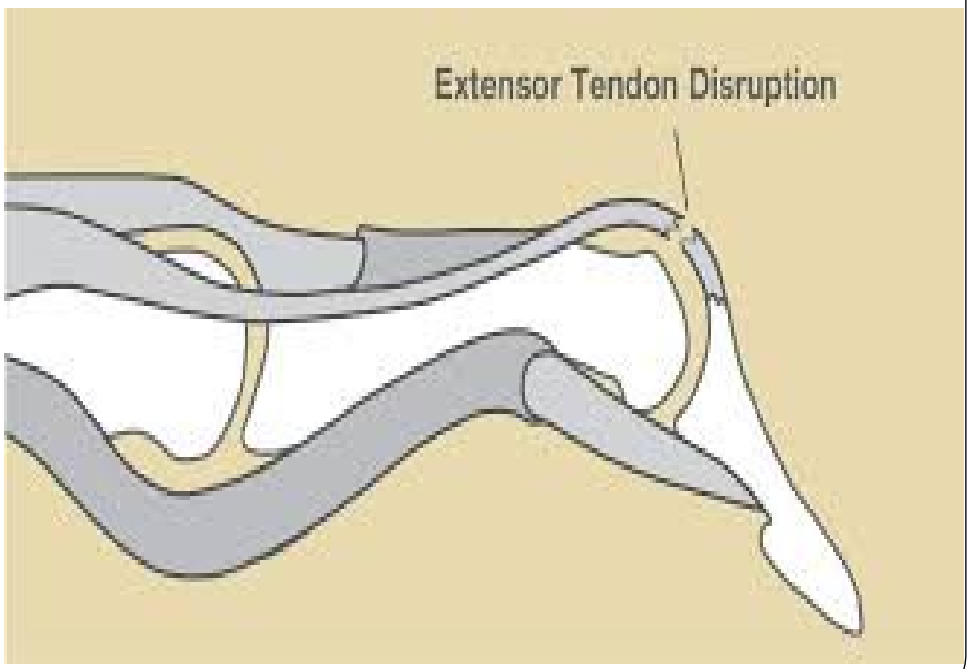
- **Swan neck deformity===** (DIP hyperflexion with PIP hyperextension).
- **Boutonniere deformity** (PIP flexion with DIP hyperextension).

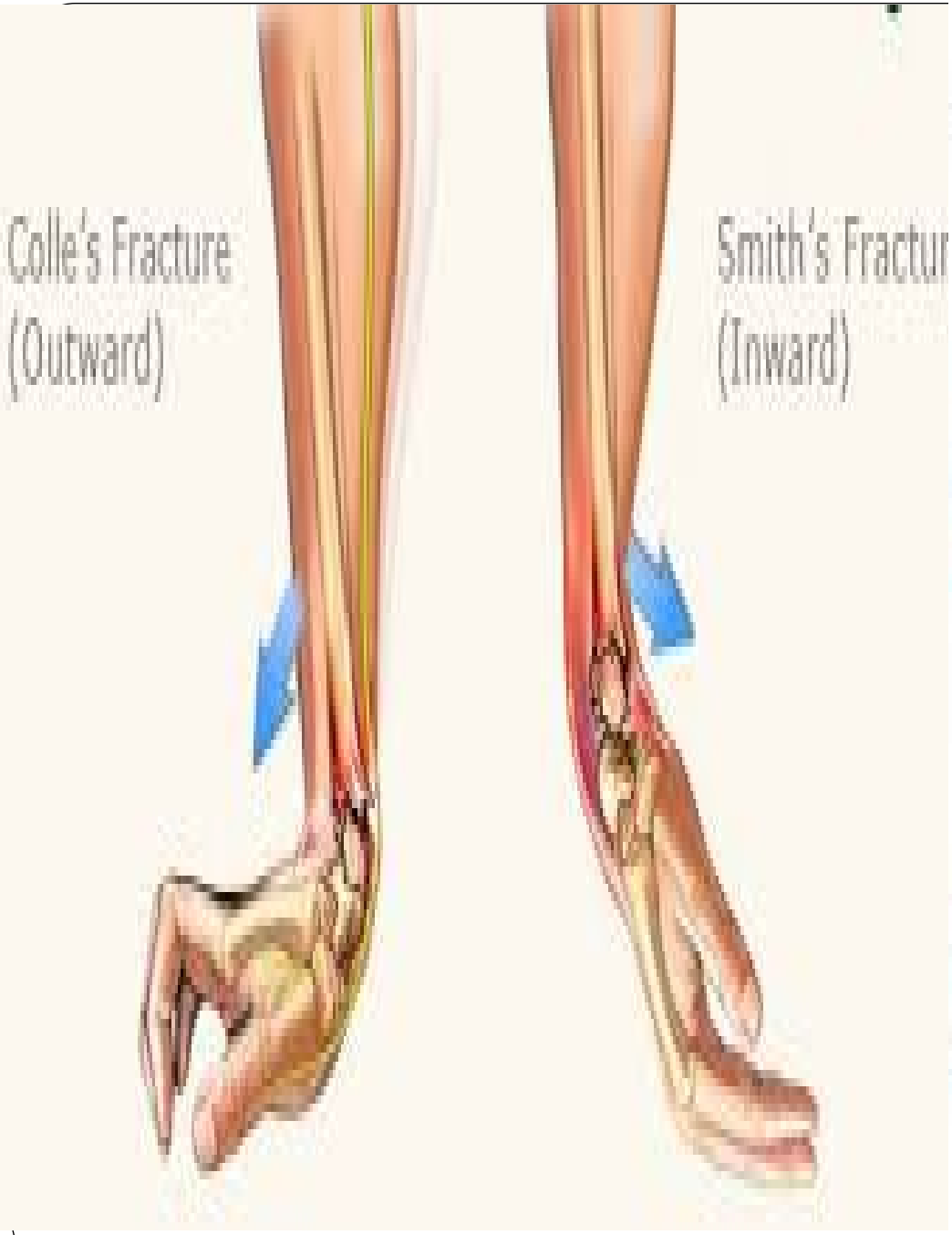


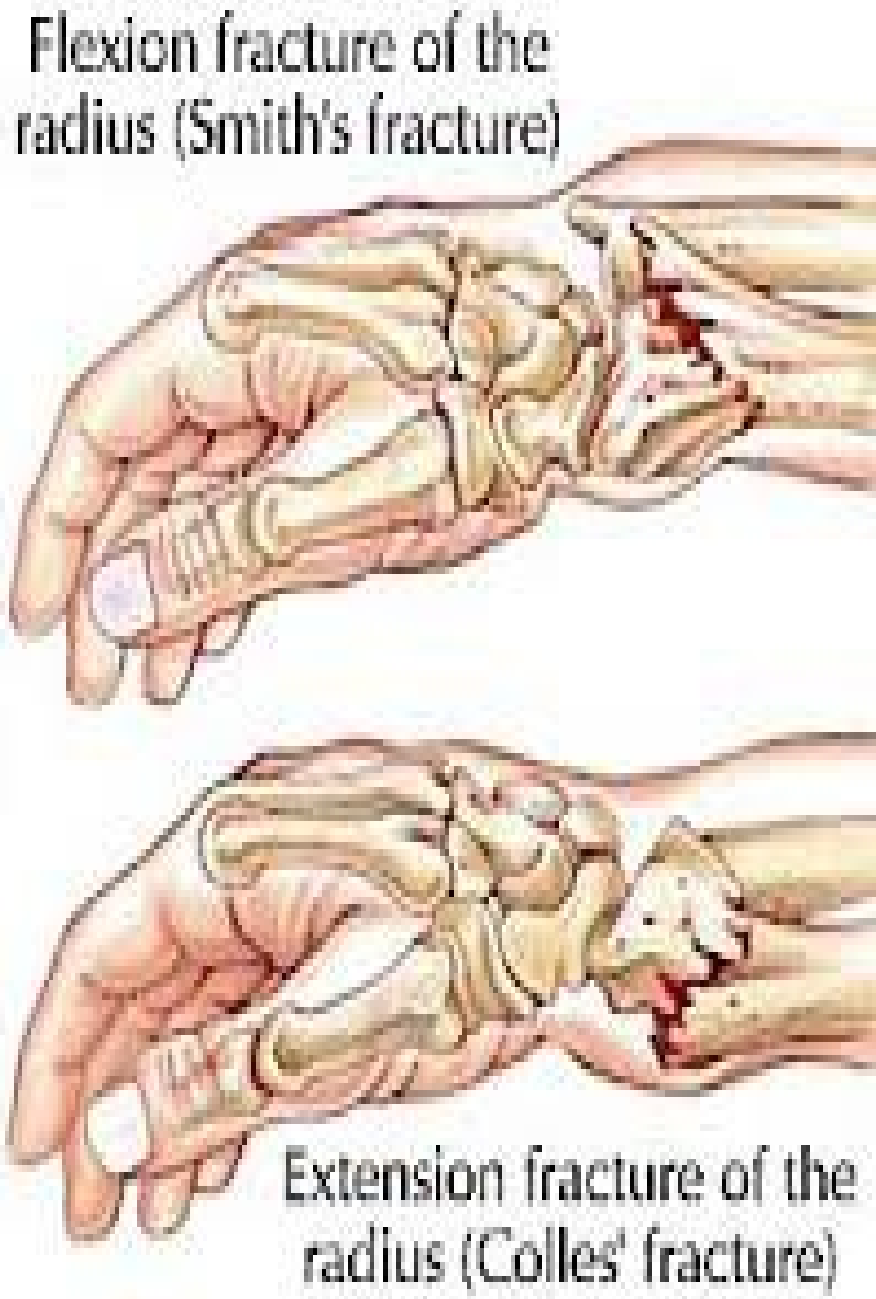


Mallet finger

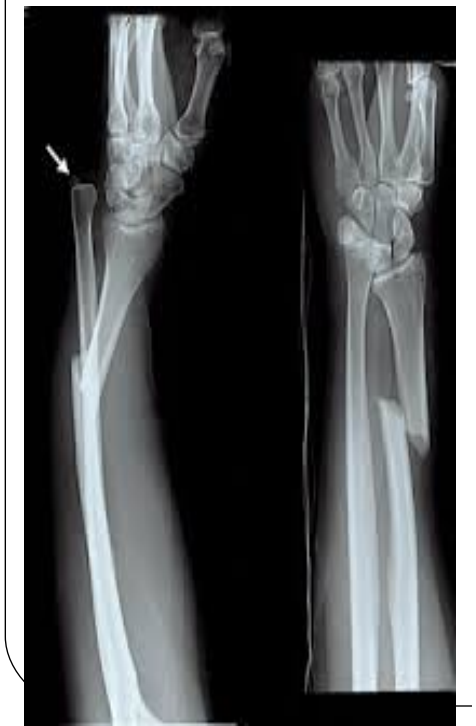
- **Mallet finger**, also **baseball finger**, **dropped finger**, **dolphin finger, due to** an injury of the extensor digitorum tendon of the fingers at the distal interphalangeal joint (DIP).

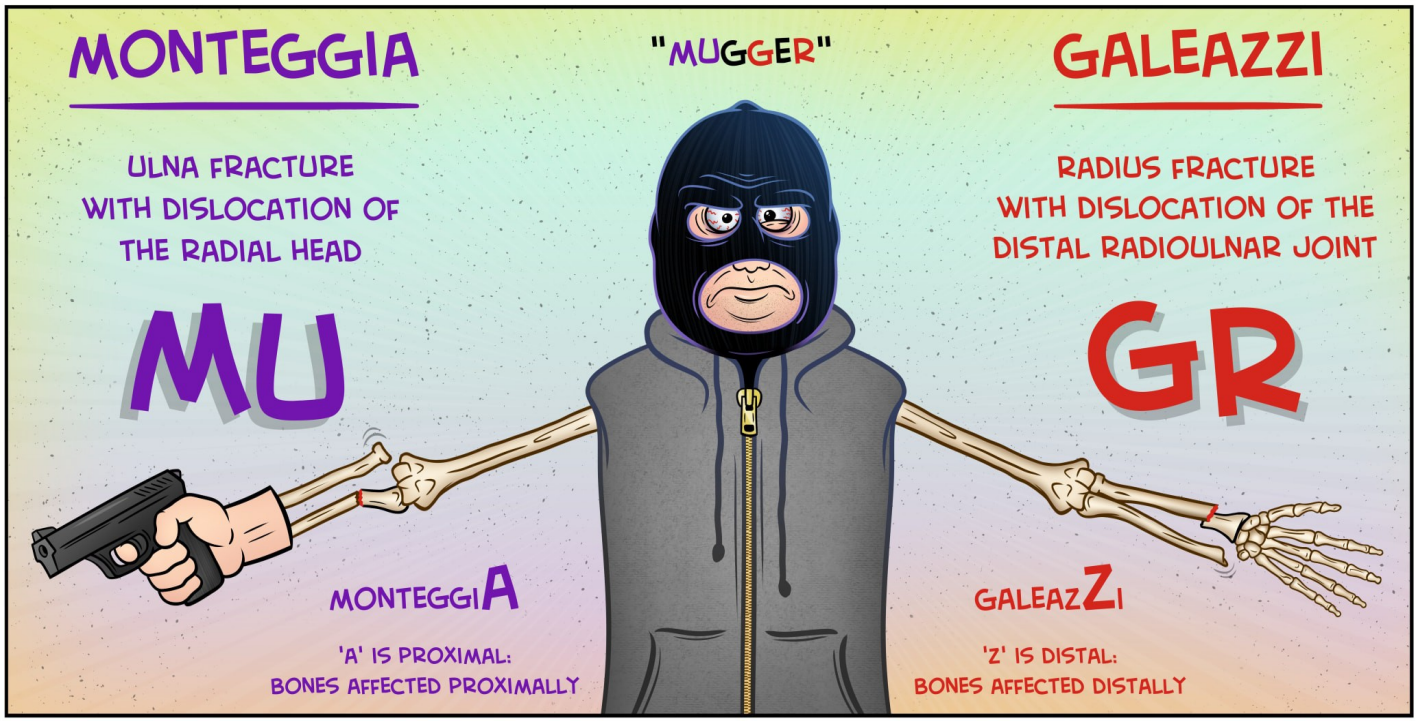



Colle's Fracture
(Outward)
Smith's Fractur
(Inward)


Flexion fracture of the radius (Smith's fracture)
Extension fracture of the radius (Colles' fracture)

- **Monteggia fracture.** This injury affects both bones of the forearm. There is usually a fracture in the upper 1/3ulna along with dislocation of radius head. This is a very severe injury and requires urgent care.
- The **Galeazzi fracture** is a **fracture** of the distal third of the radius with dislocation of the distal radioulnar joint.

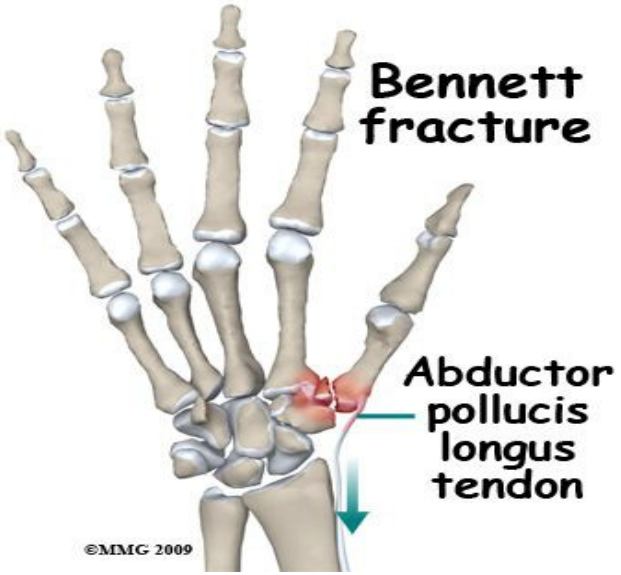




Bennett fracture:

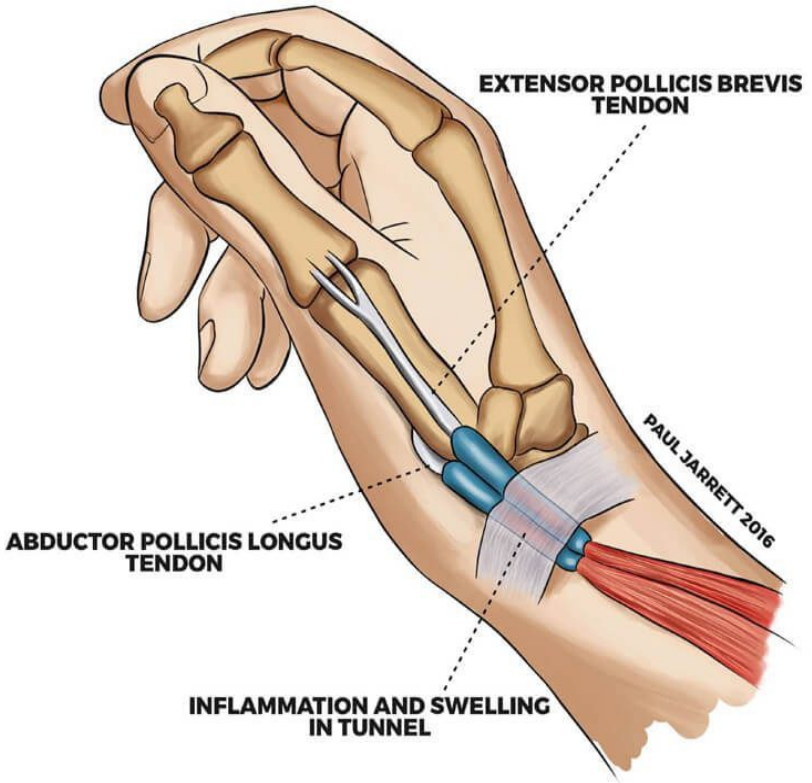
A fracture of the base of the **first metacarpal bone** which extends into the carpometacarpal (CMC) joint.

This intra-articular **fracture** is most common **fracture** of thumb, and is accompanied by some degree of subluxation or dislocation of the carpometacarpal joint.



De-quervain's tenosynovitis

- A painful inflammation of tendons(Abd. PolLicis longus & ext.pollicis brevis) in your wrist and base of thumb.
- When the swollen tendons rub against the narrow tunnel(anatomical snuff box) it causes pain at the base of your thumb and into the lower arm.



Claw hand:

- Also known as **ulnar claw**, ' is a deformity or an abnormal attitude of the hand that develops due to ulnar nerve damage causing paralysis of the lumbricals.
- A claw hand presents with a hyperextension at the metacarpo-phalangeal joints and flexion at the proximal and distal inter-phalangeal joints of the 4th and 5th fingers