Wrist biomechanics and instability - disruption of the scapholunate ligament

Mariusz Bonczar

THE 2nd INTERNATIONAL TRAUMA SYMPOSIUM
Injuries of the Upper Extremity - from top to bottom

Special thanks to Marc Garcia Elias

Understanding Wrist Mechanics: A Long and Winding Road*

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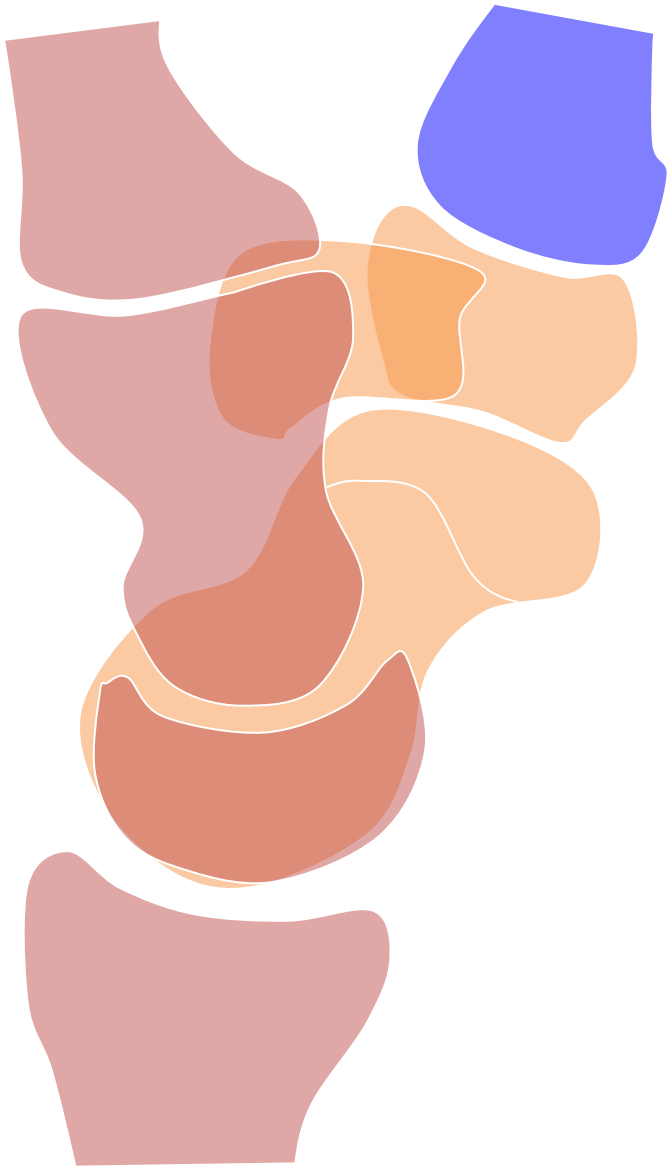
J Wrist Surg 2013;2:5–12.

The latest in wrist biomechanics

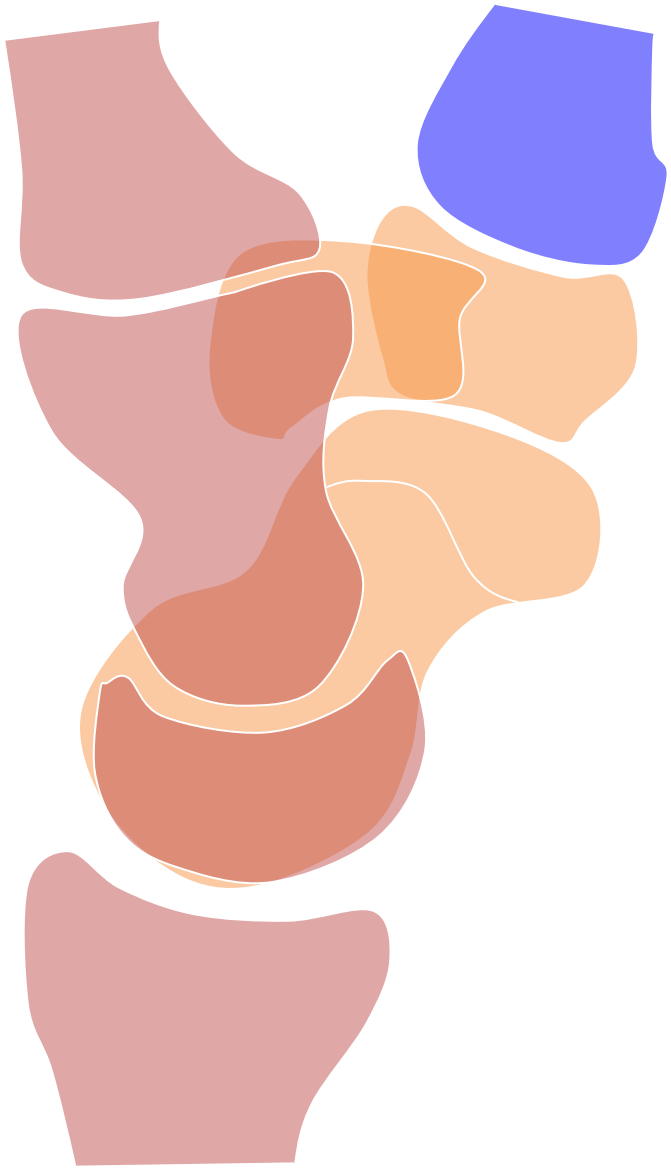
- **From a kinematic point of view, the midcarpal joint is more important than the radiocarpal joint**
- There are different patterns of wrist motion
- Loads across the carpus are much higher than previously assumed
- Ligaments are sensory structures with an important proprioceptive role in carpal stability
- Muscles are the ultimate stabilizers of the wrist

The proximal row has no tendon insertions



The proximal row has no tendon insertions

Wrist motion always starts at the distal row



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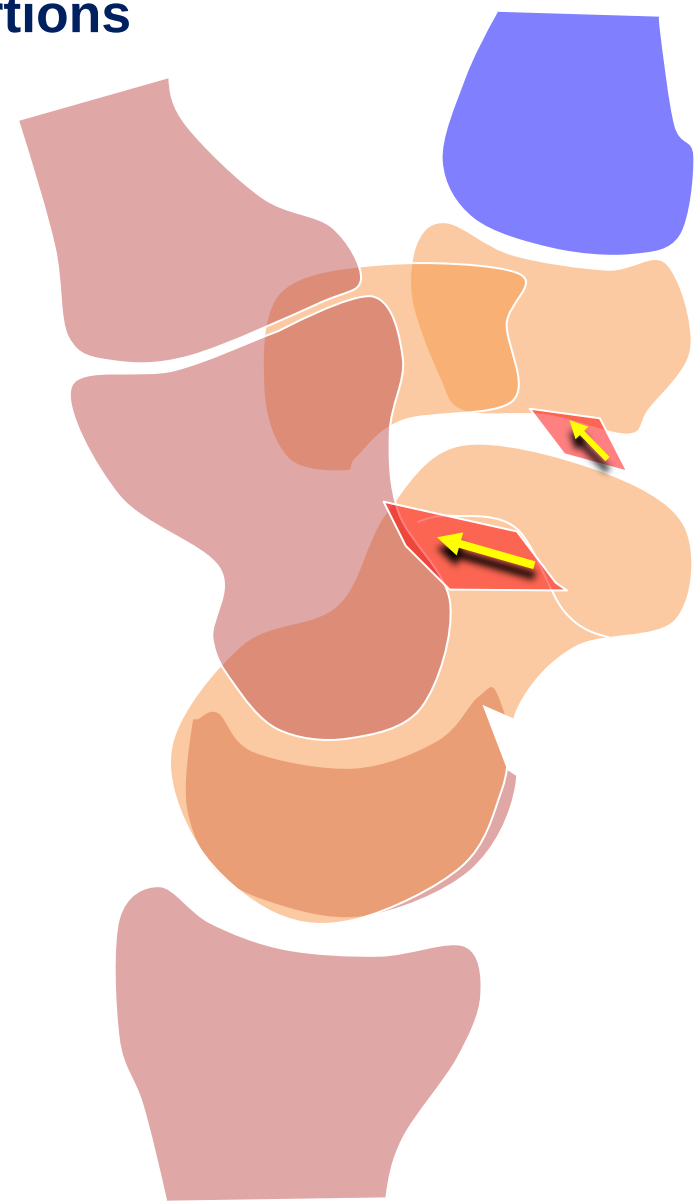
Progressively, the midcarpal ligaments become taut…



The proximal row has no tendon insertions

Wrist motion always starts at the distal row

Progressively, the midcarpal ligaments become taut…

and compressive load appears at the midcarpal joint…

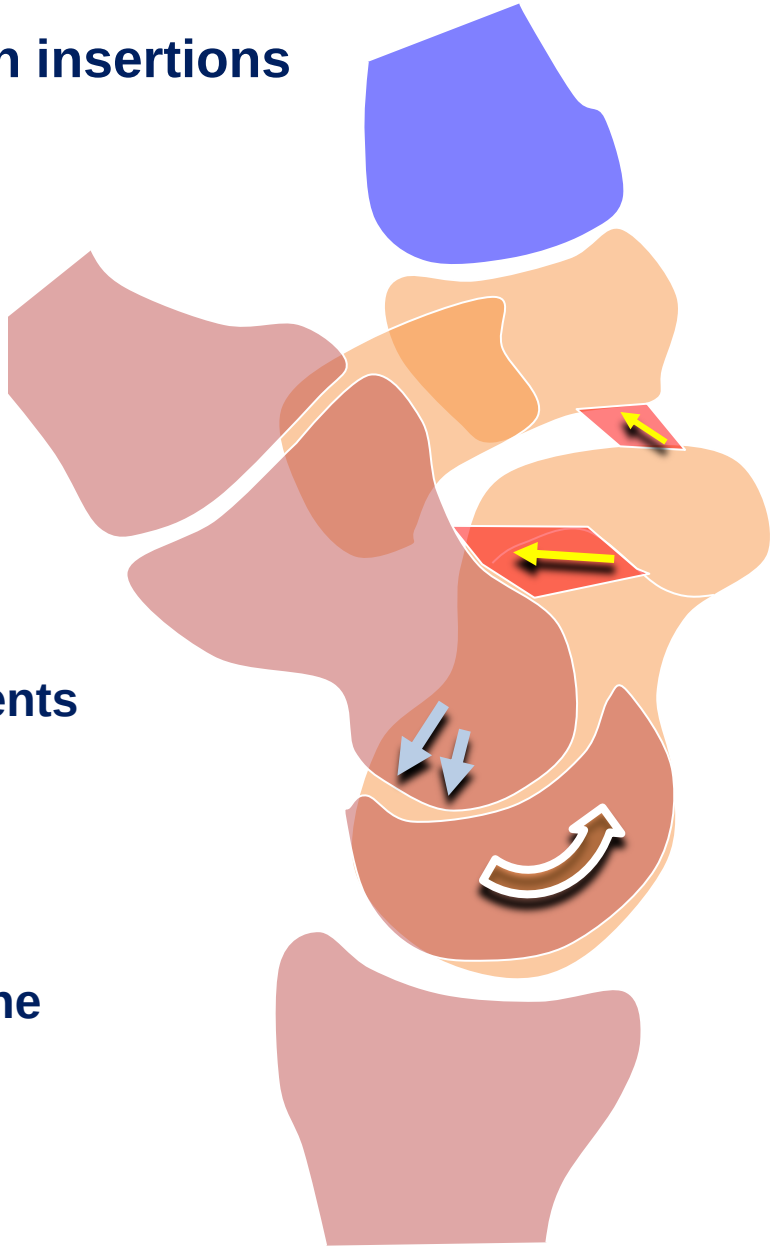
The proximal row has no tendon insertions

Wrist motion always starts at the distal row

Progressively, the midcarpal ligaments become taut…

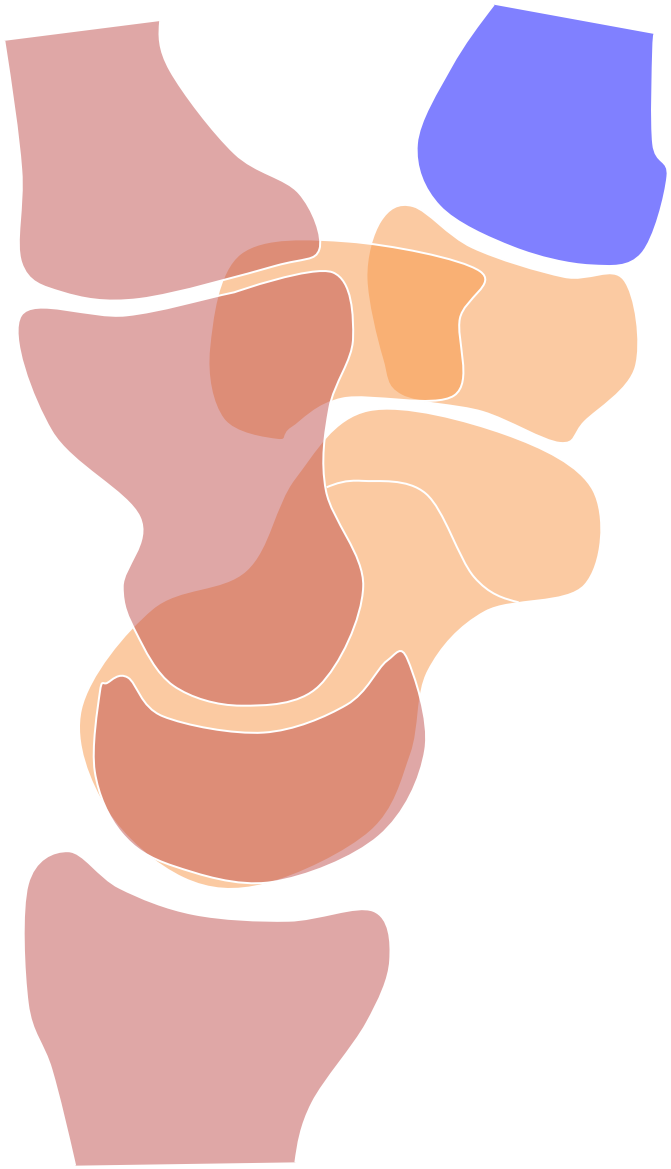
and compressive load appears at the midcarpal joint…

….forcing the proximal row to move



Around the neutral position

there is only MC rotation



Around the neutral position

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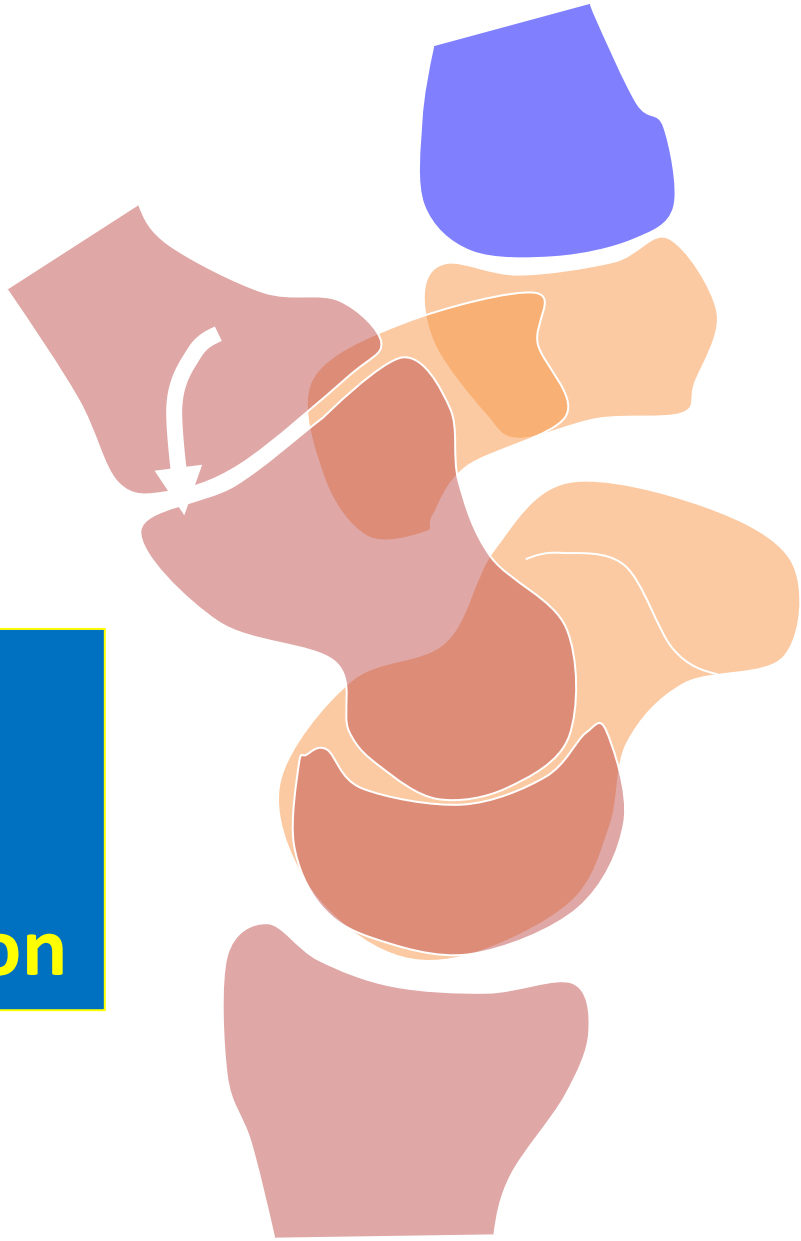

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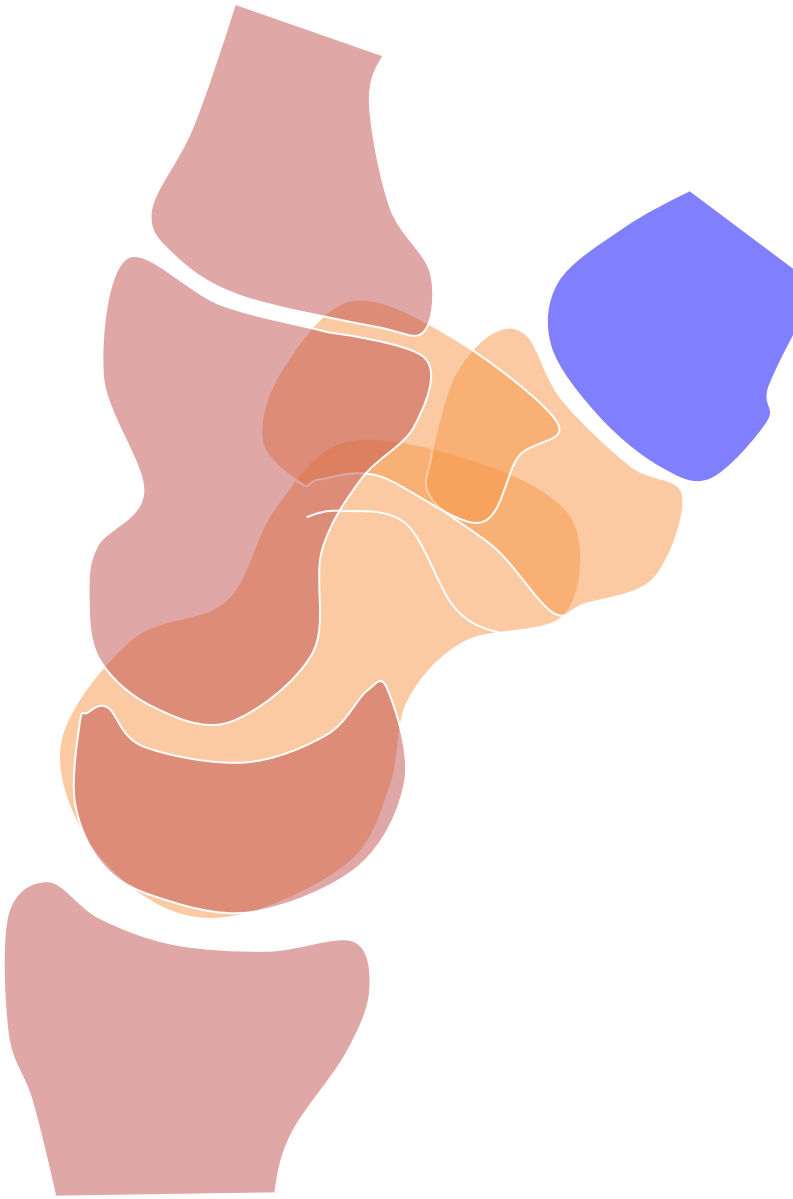
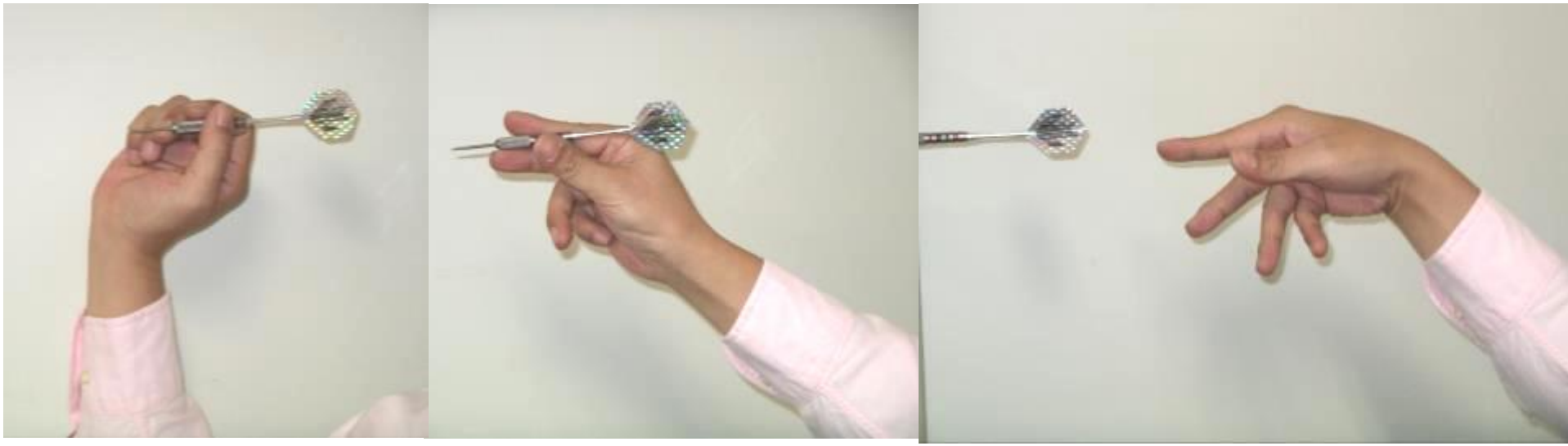


Dart Thrower's Motion (DTM)



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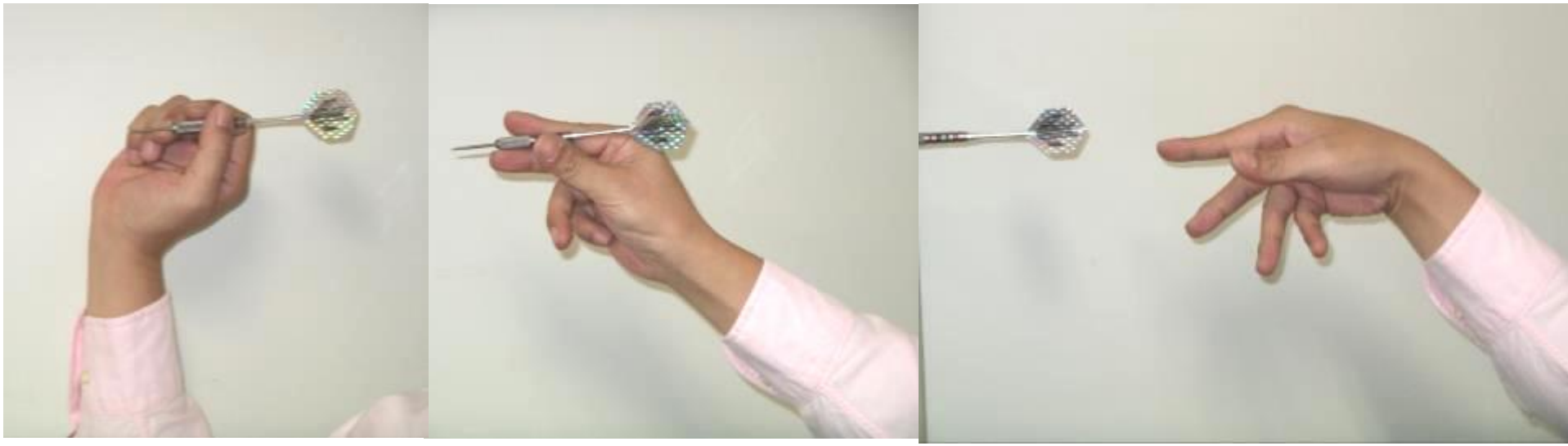
Moritomo H,, et al. (2007) *IFSSH committee report of wrist biomechanics committee: biomechanics of the so-called dart-throwing motion of the wrist*. J Hand Surg Am;32:1447-1453.
Brigstocke GHO, et all (2014) . *In-vivo confirmation of the use of the dart thrower's motion during activities of daily livin*g. J Hand Surg Eur 39:373-378.

Dart Thrower's Motion (DTM)

- oblique plane of movement
  - radial deviation with extension to ulnar deviation with flexion.
  - using a hammer, combing hair or pouring from a jug.



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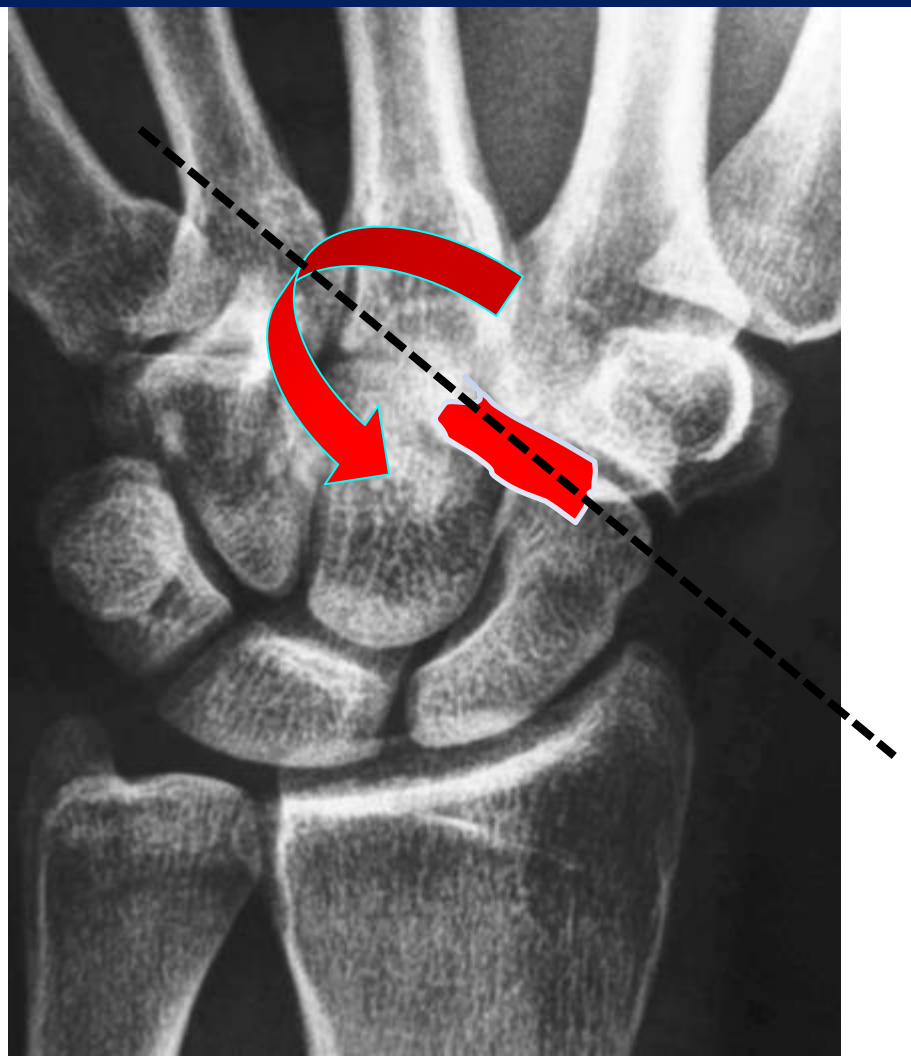
Axis of DTM

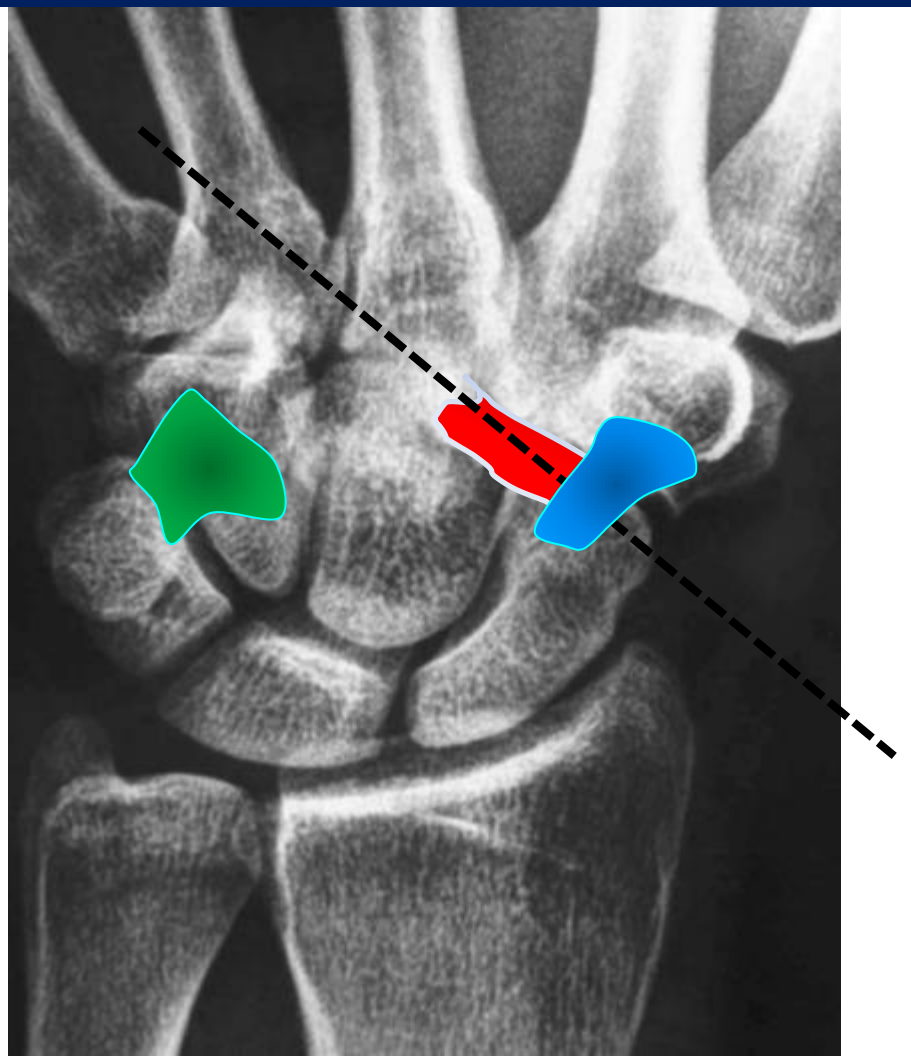
- SC ligament lies along axis of rotation



Axis of DTM

- SC ligament lies along axis of rotation

- Checkreins
  - STT limits UF
  - triquetro-hamate limits RE



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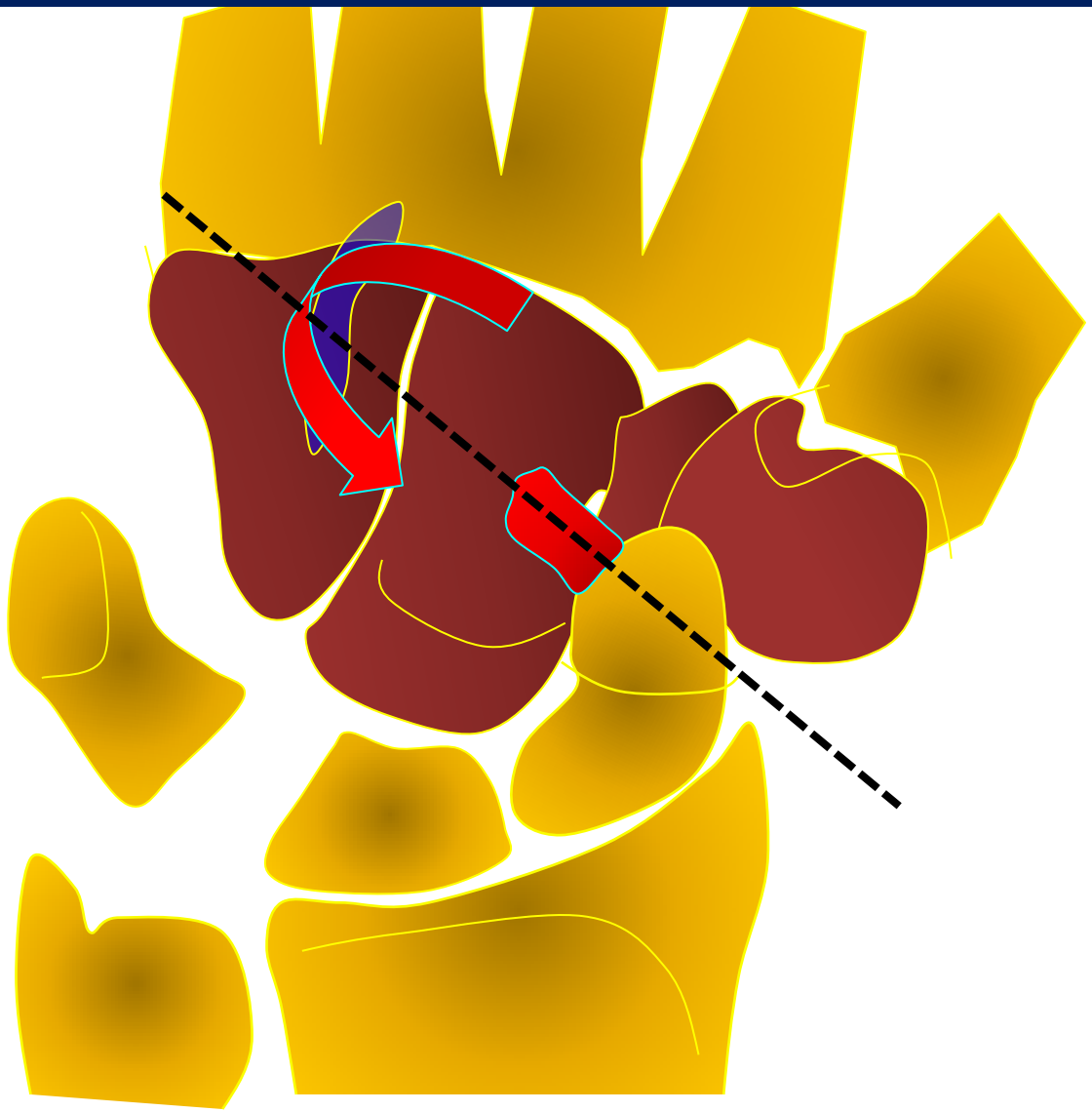

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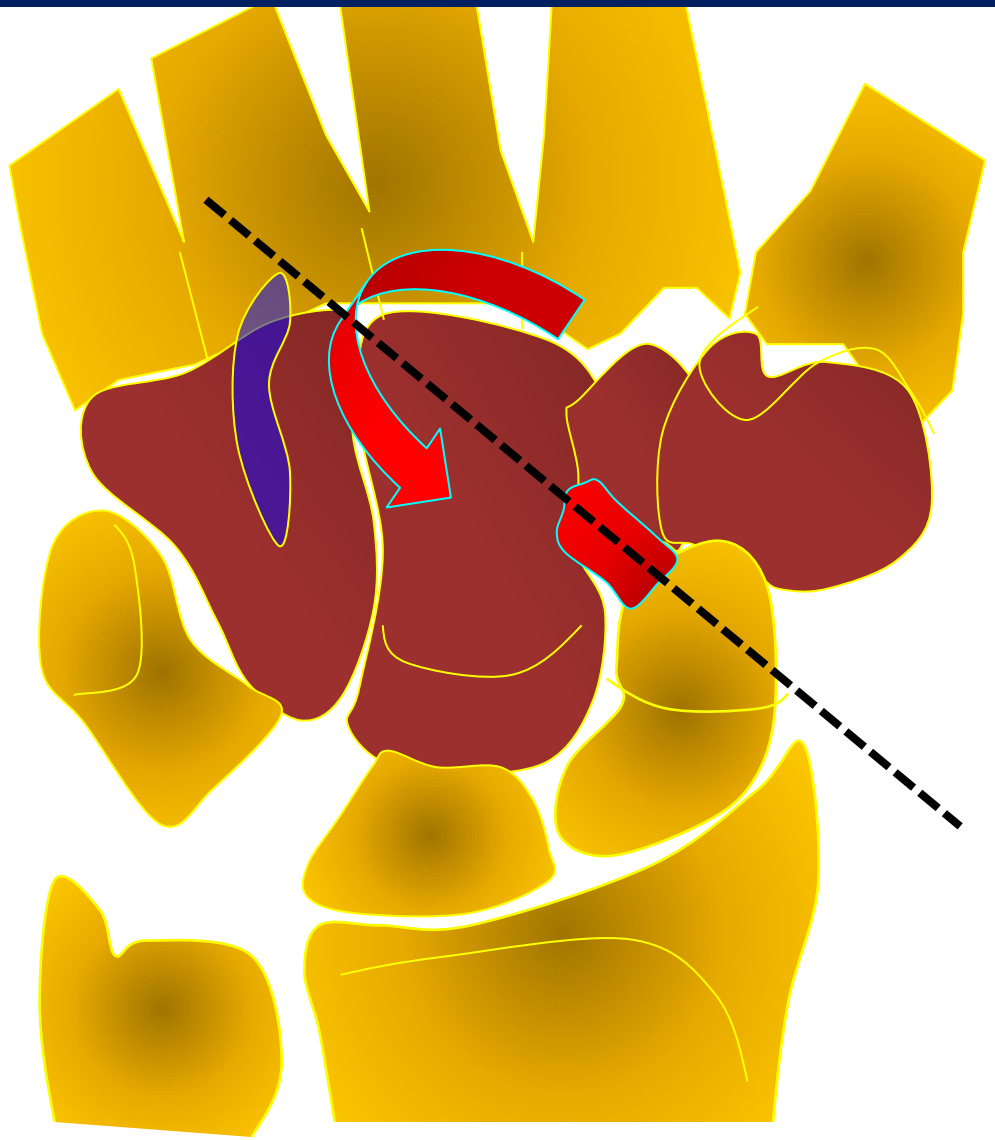

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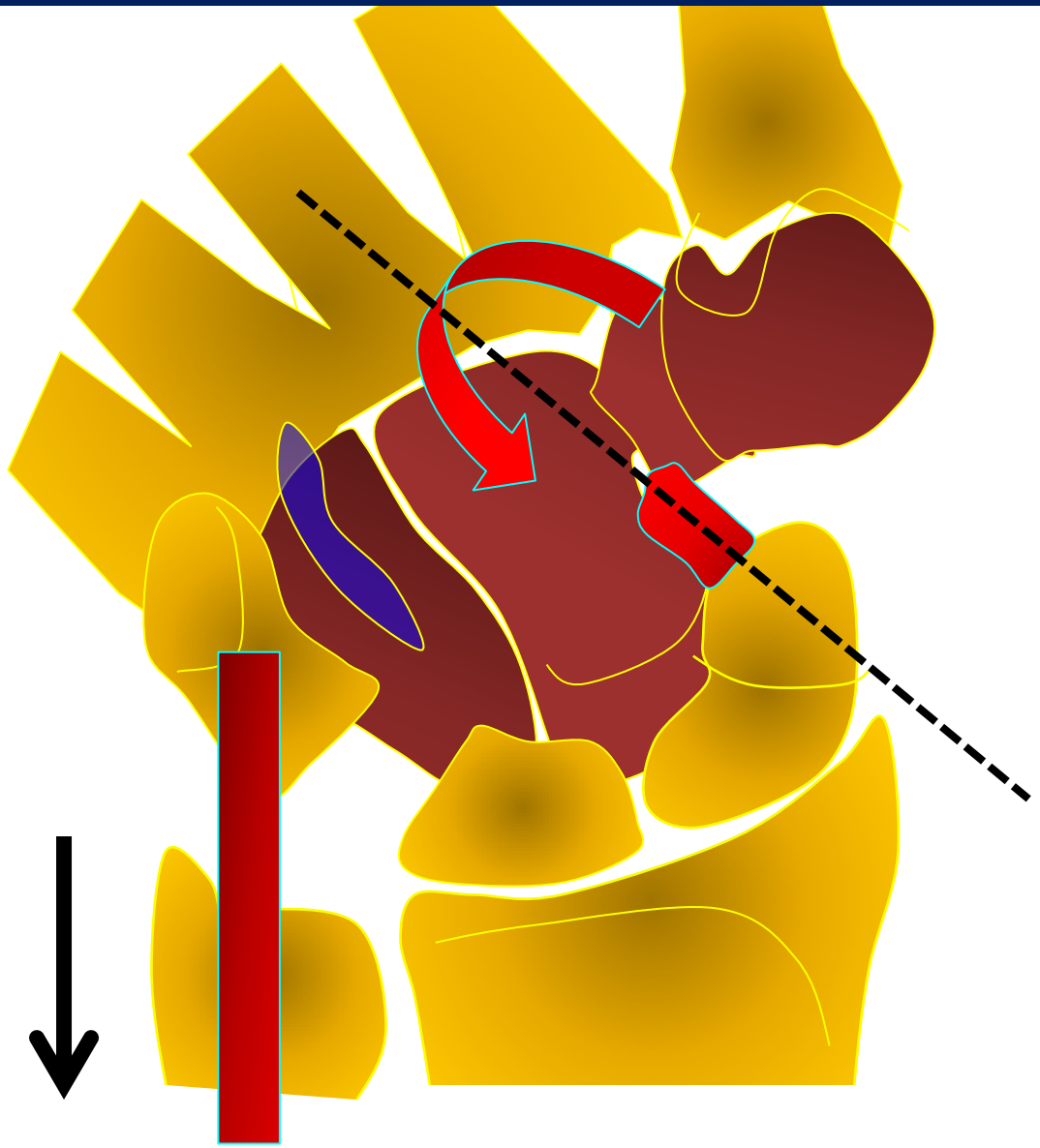

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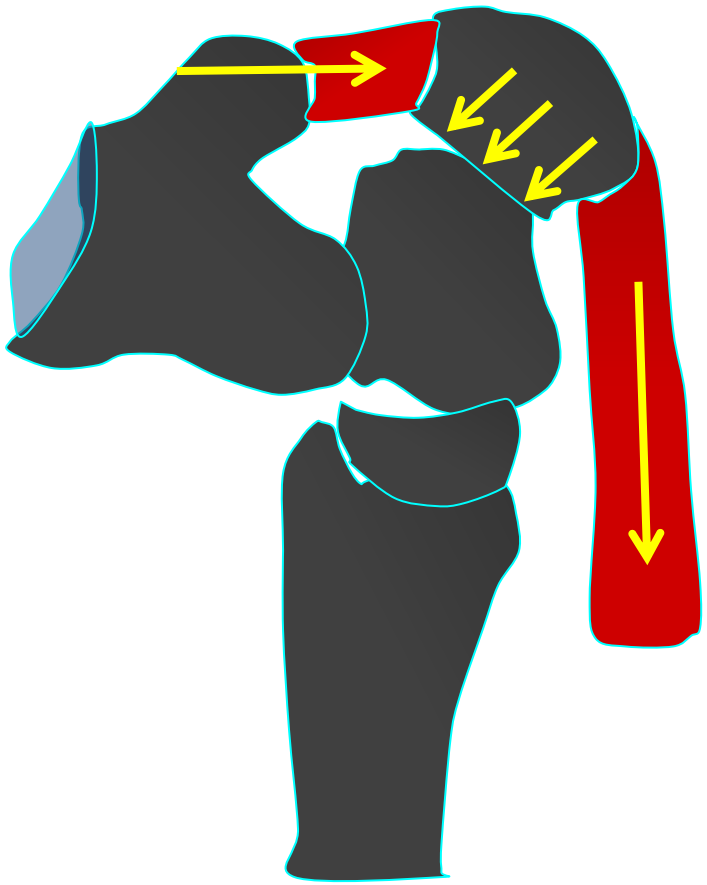
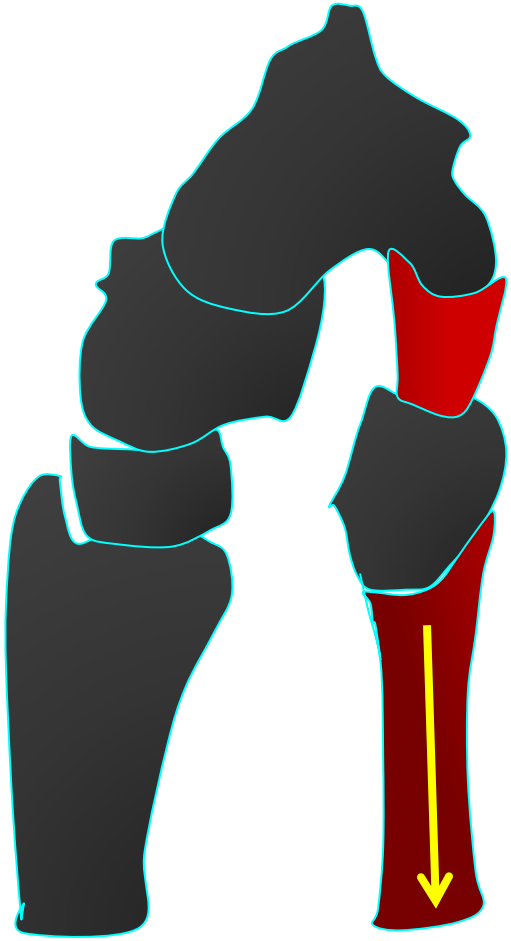


- Pisiform

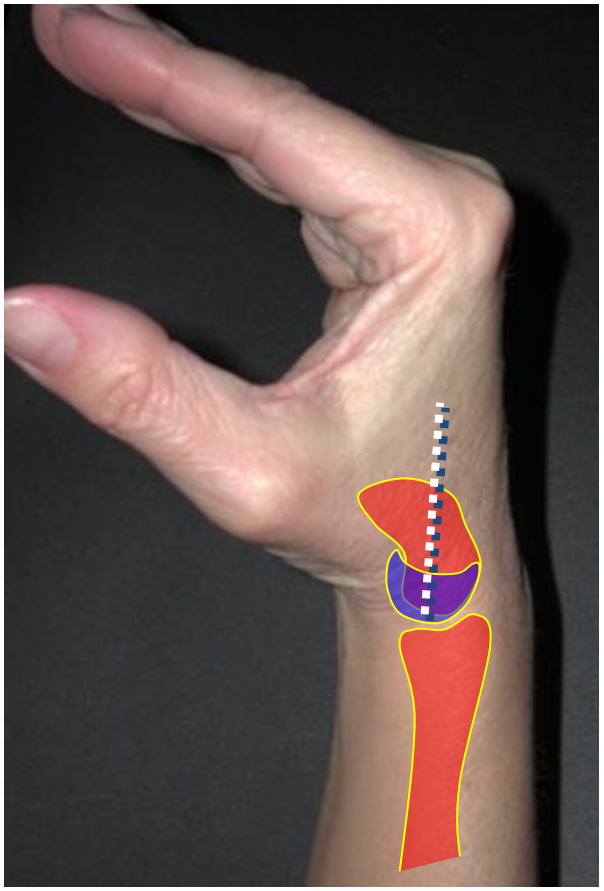
Pivot in ulnar flexion

Dart Thrower's Motion (DTM)

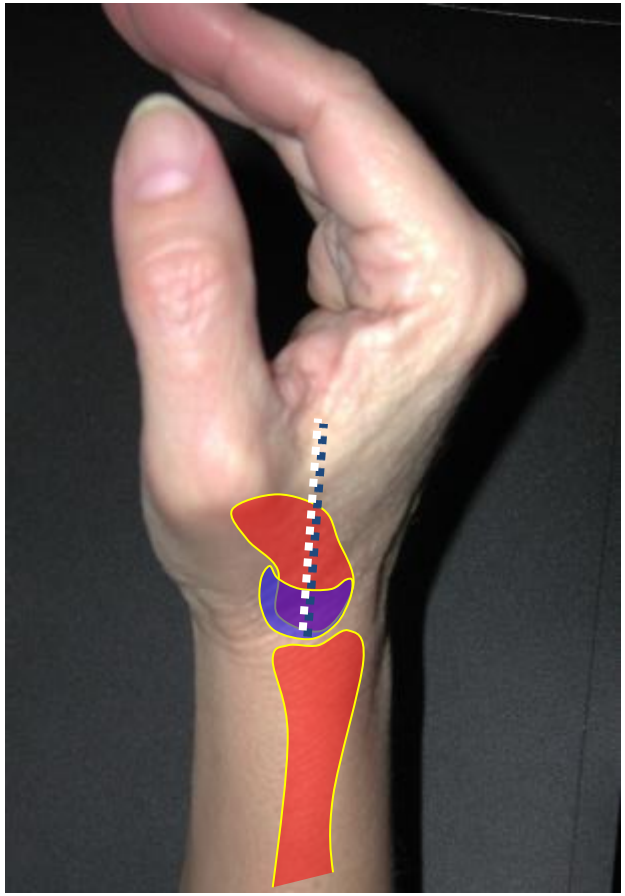


- Pisiform

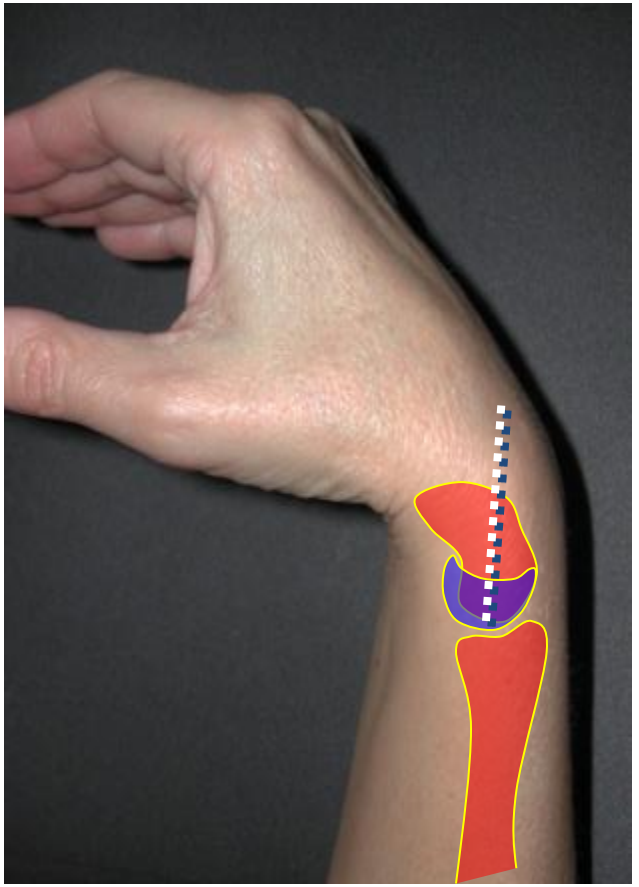
Pivot in ulnar flexion



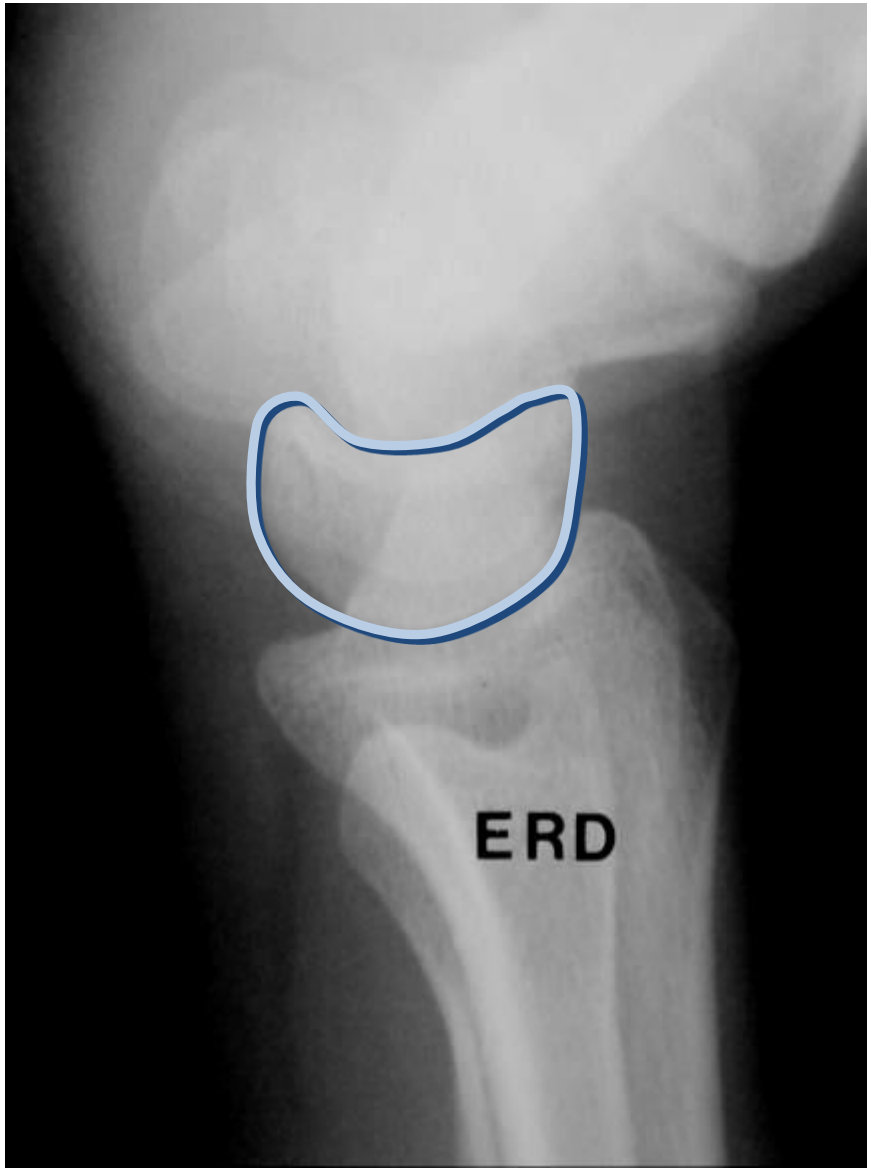
NEUTRAL

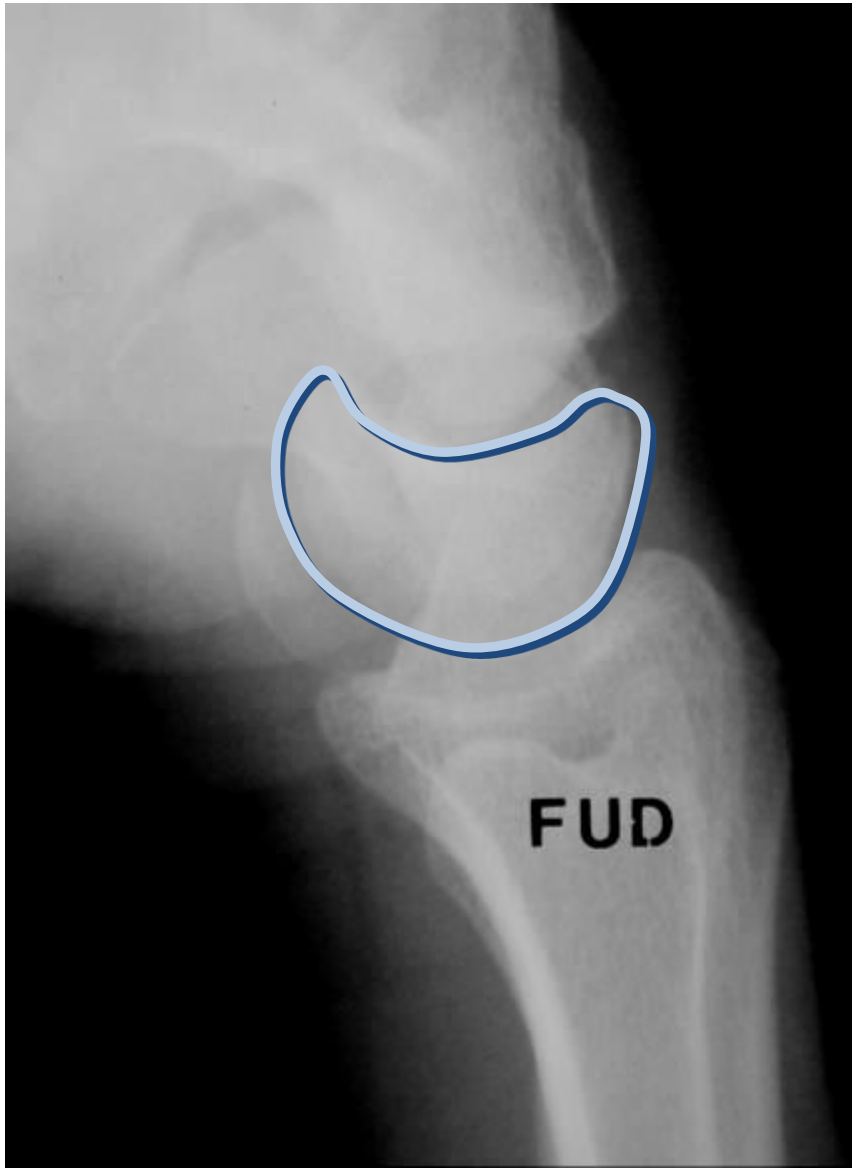


RADIAL INCL.+
EXTENSION

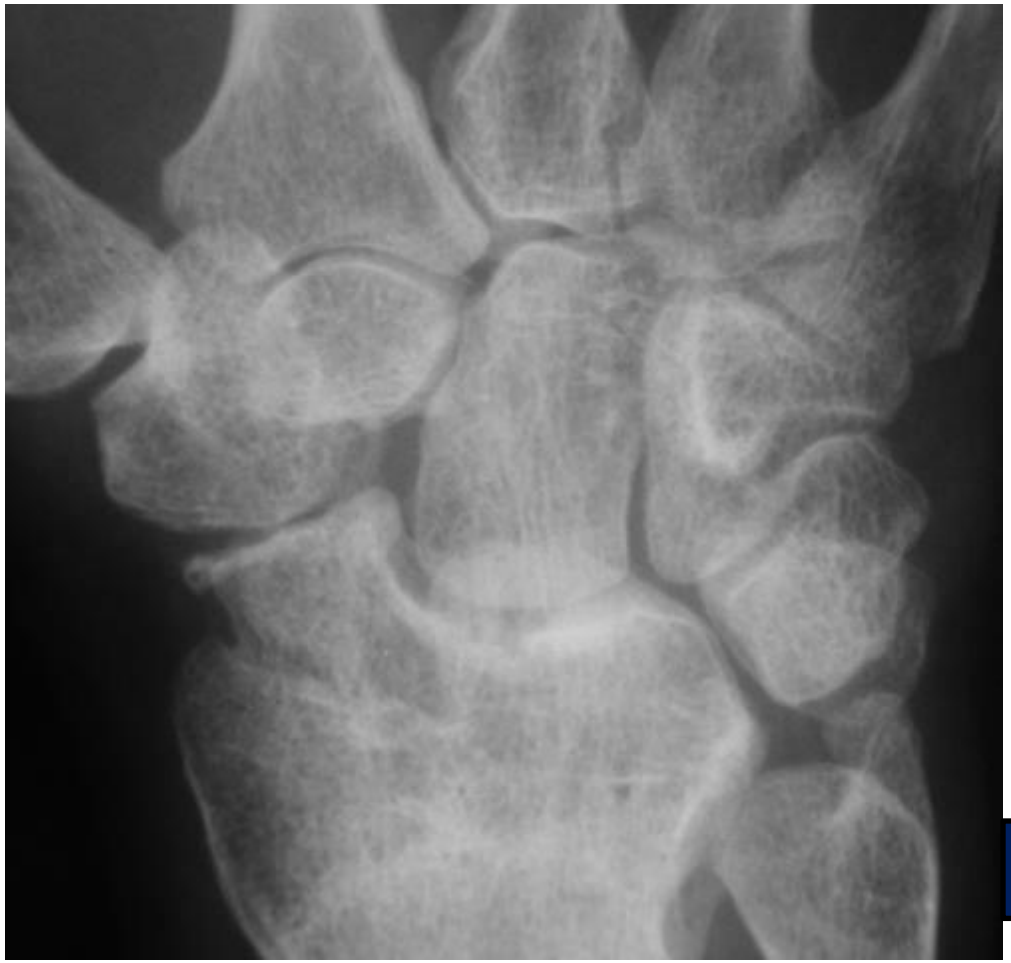


ULNAR INCL.+
FLEXION





Dart-throwing motion ➡ Lunate does not rotate



.. normal “dart-throwing”

The latest in wrist biomechanics

- From a kinematic point of view, the midcarpal joint is more important than the radiocarpal joint
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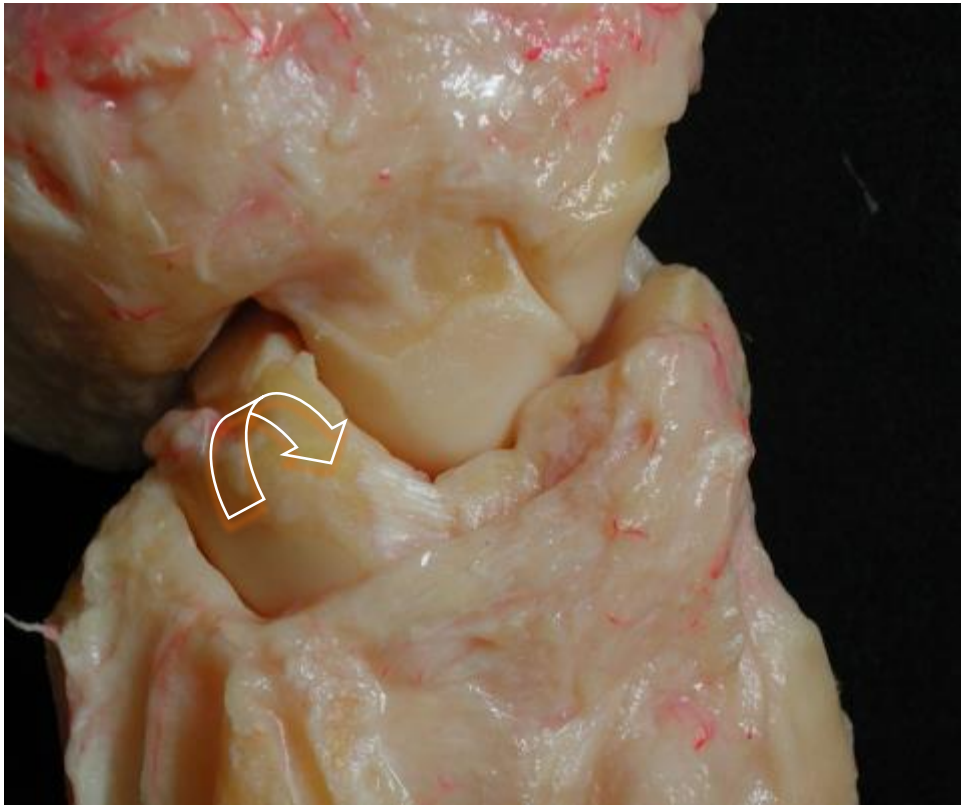
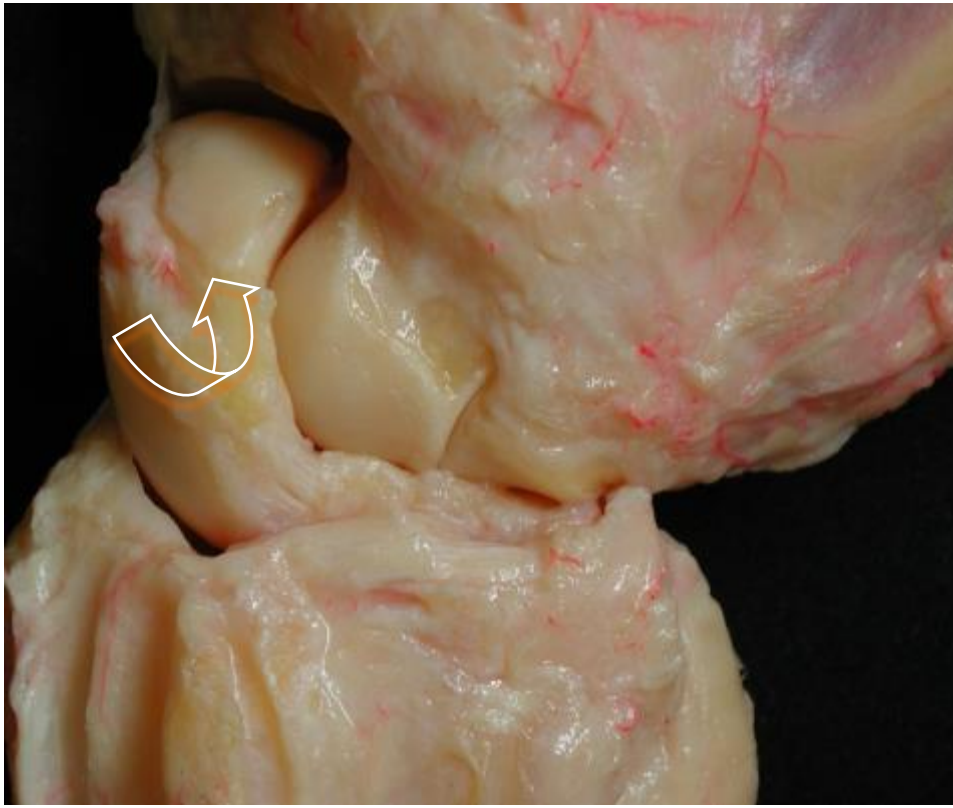
RADIAL DEVIATION

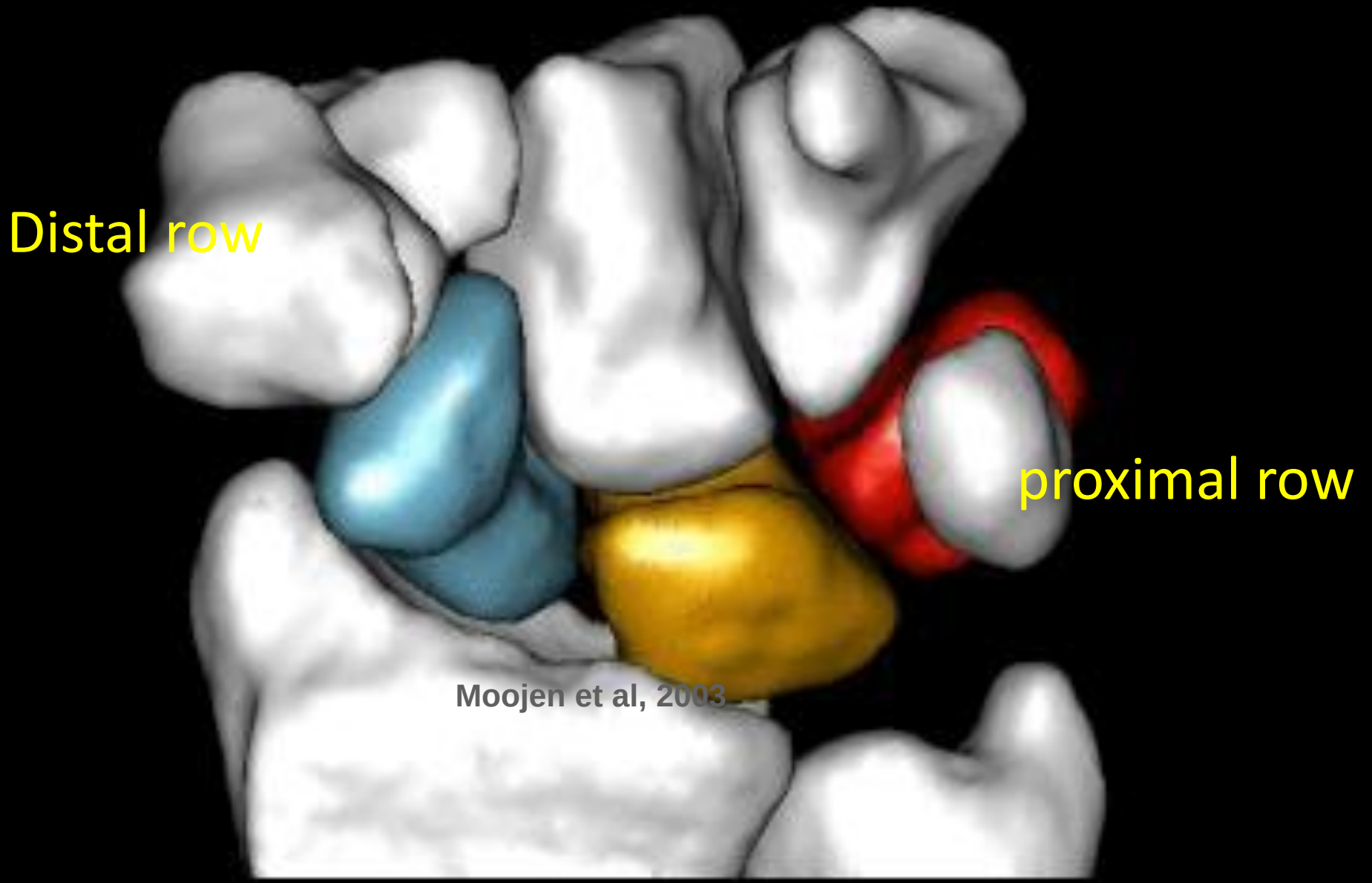
ULNAR DEVIATION

FLEXION

EXTENSION

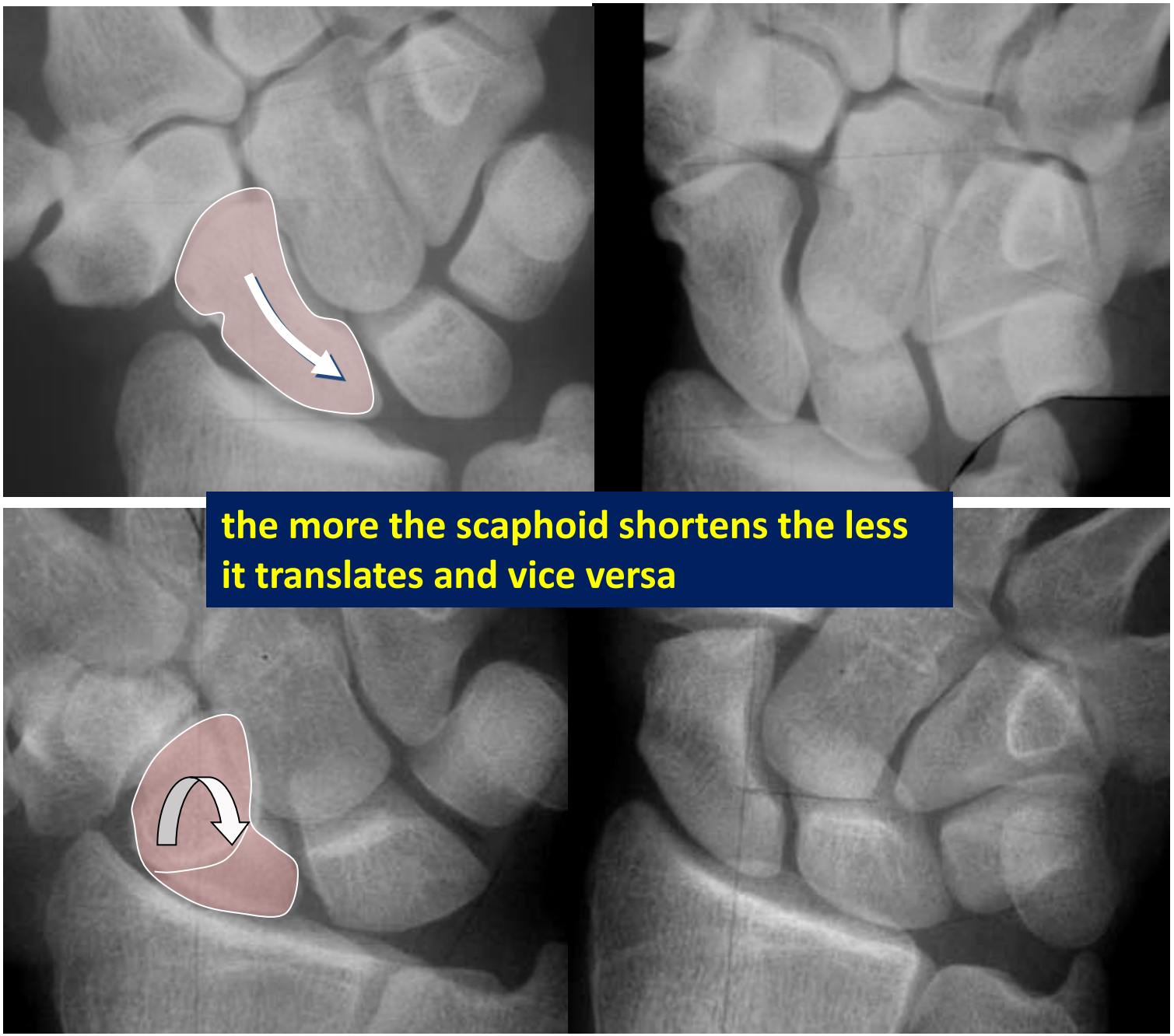





Distal row
proximal row
Moojen et al, 2003


Rtg nadgarstka/dlon
767 [D]


Rtg nadgarstka/dloni
R
WW: 32767 [D]



the more the scaphoid shortens the less it translates and vice versa

Craigen & Stanley 1995

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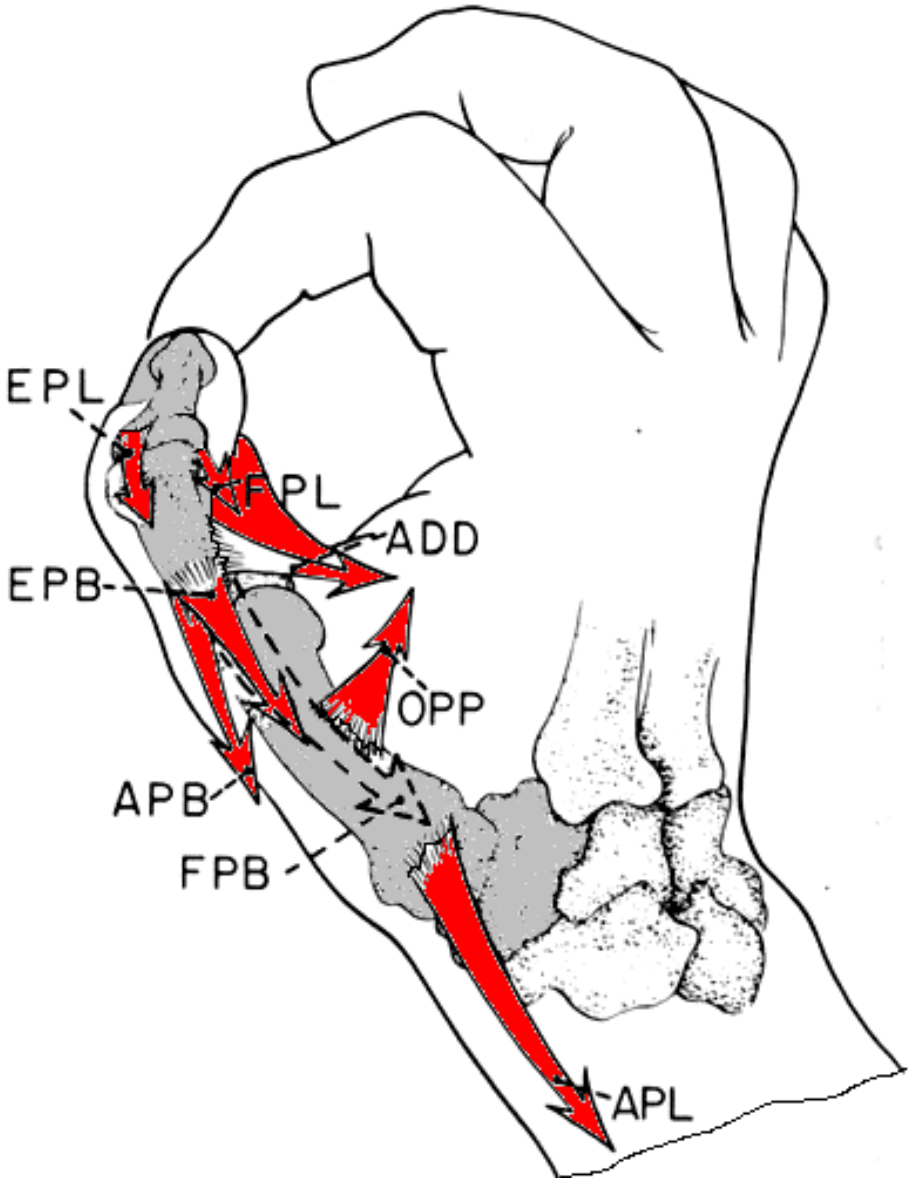


Tip pinch
(1 kgr)

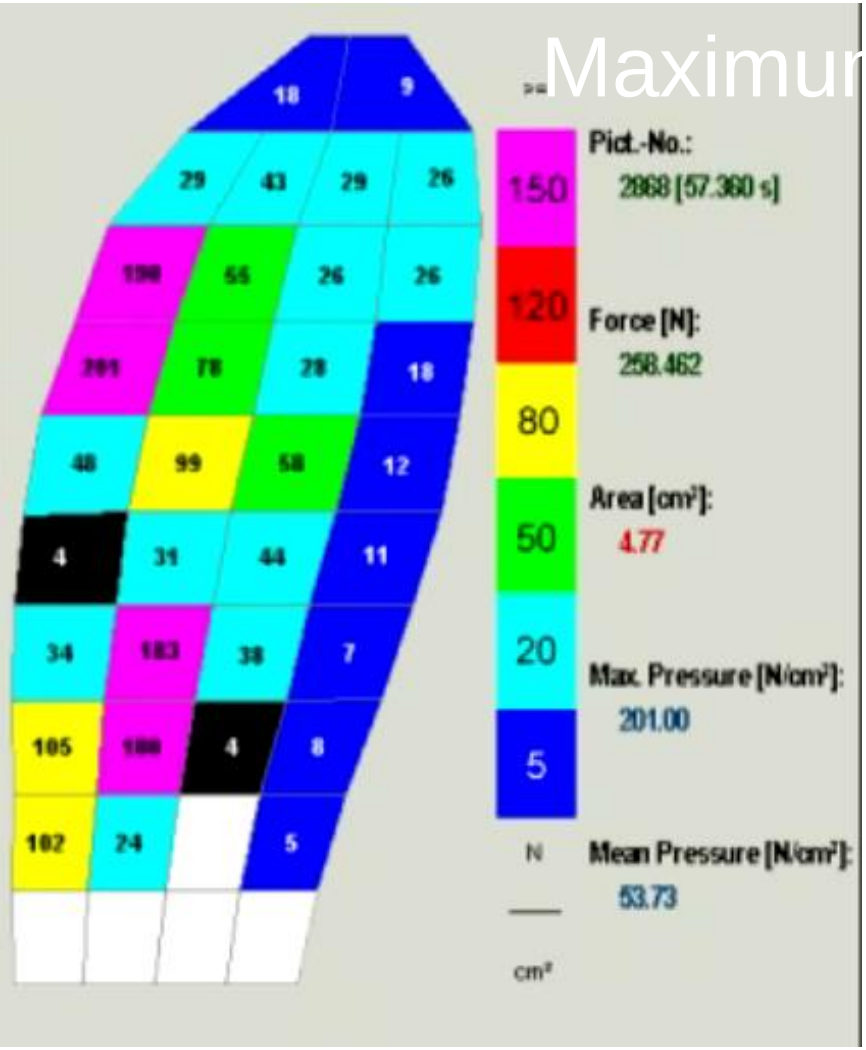
TMC
(6.4–13.4 kgr)

Cooney WP & Chao EYS: Biomechanical analysis of static forces in the thumb during hand function. J Bone Joint Surg 59A:27-36,1977

Intra-Articular Pressure Measurement in the Radioulnocarpal Joint Using a Novel Sensor: *In Vitro* and *In Vivo* Results

Daniel A. Rikli, MD, Philipp Honigmann, MD, Reto Babst, MD,
Alessandra Cristalli, PhD, Michael M. Morlock, PhD,
Thomas Mittlmeier, MD

Rikli et al. J Hand Surg 32A:67-75,2007



Mean pressure: 54 N / cm^2

Maximal pressure: 201 N / cm^2

Total force: 258 Newtons

Rikli et al. J Hand Surg 32A:67-75,2007

Results: The sensor delivered reproducible measurements of forces across the radioulnocarpal joint and their distribution in the cadaver experiment. *In vivo,* 2 centers of force transmission were identified. None of these centers correlated with previous findings in the literature. More force is transmitted across the ulnar side of the radioulnocarpal joint than previously thought. The results are consistent with clinical findings.

Rikli et al. J Hand Surg 32A:67-75,2007

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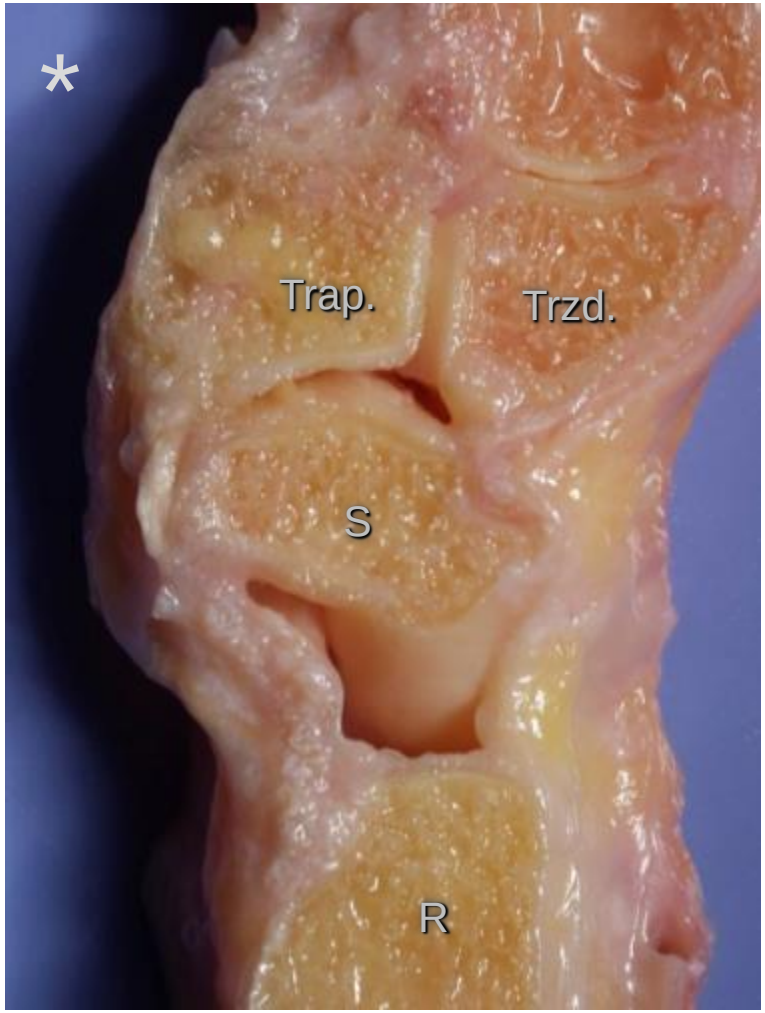
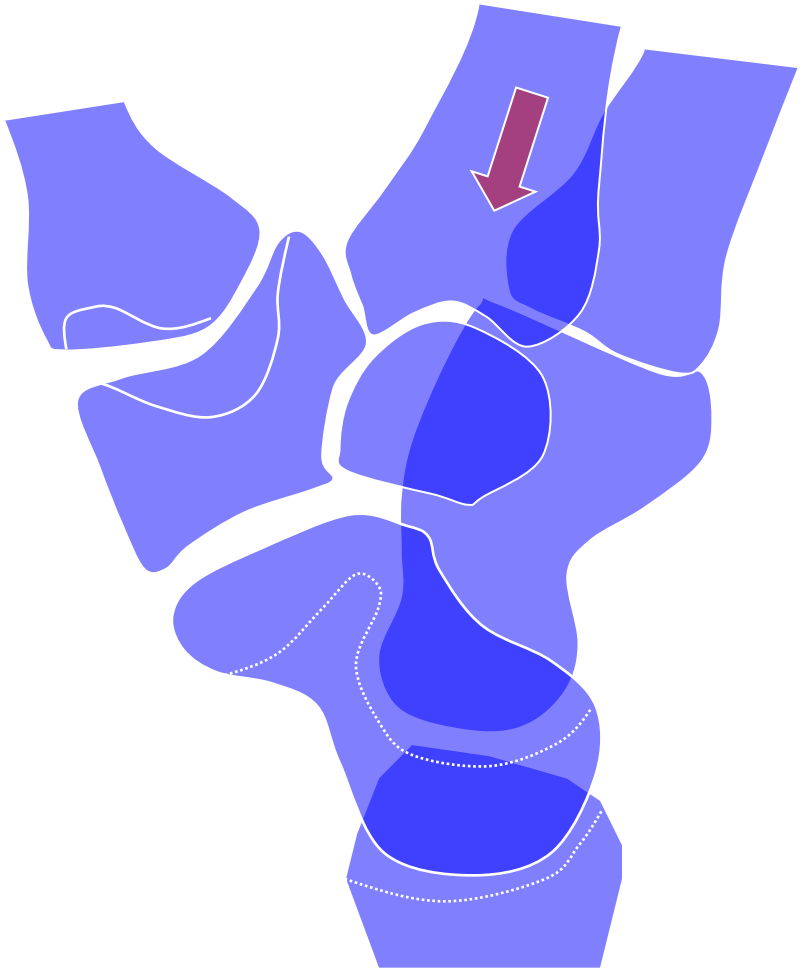
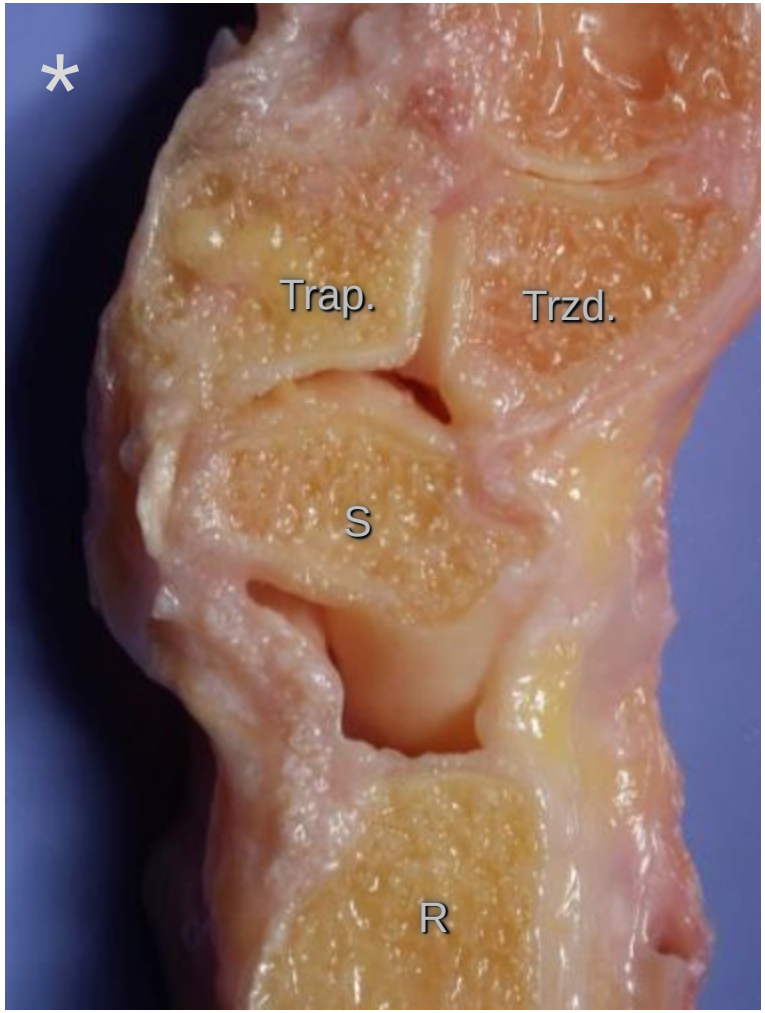
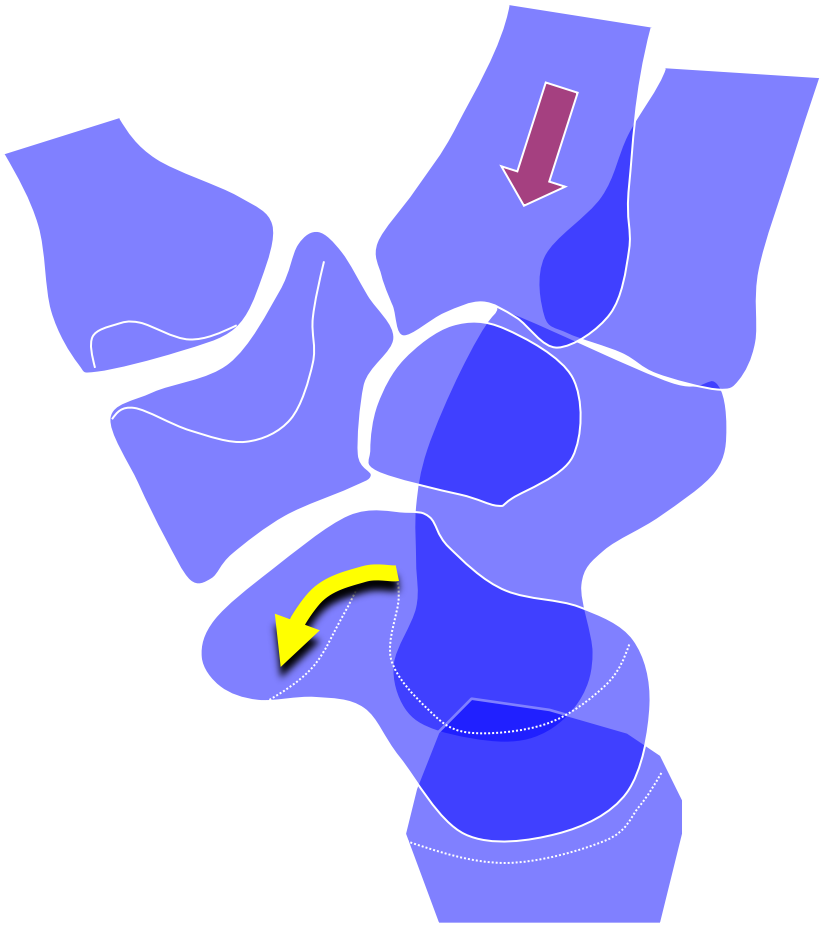




Under load, the scaphoid flexes,…





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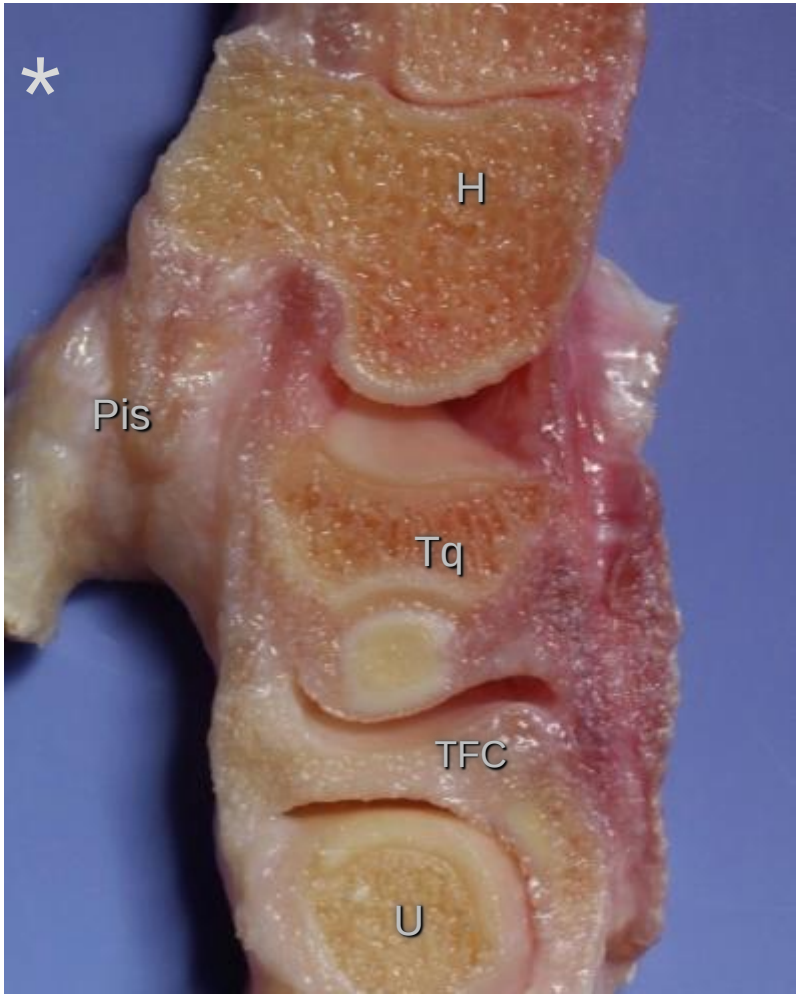
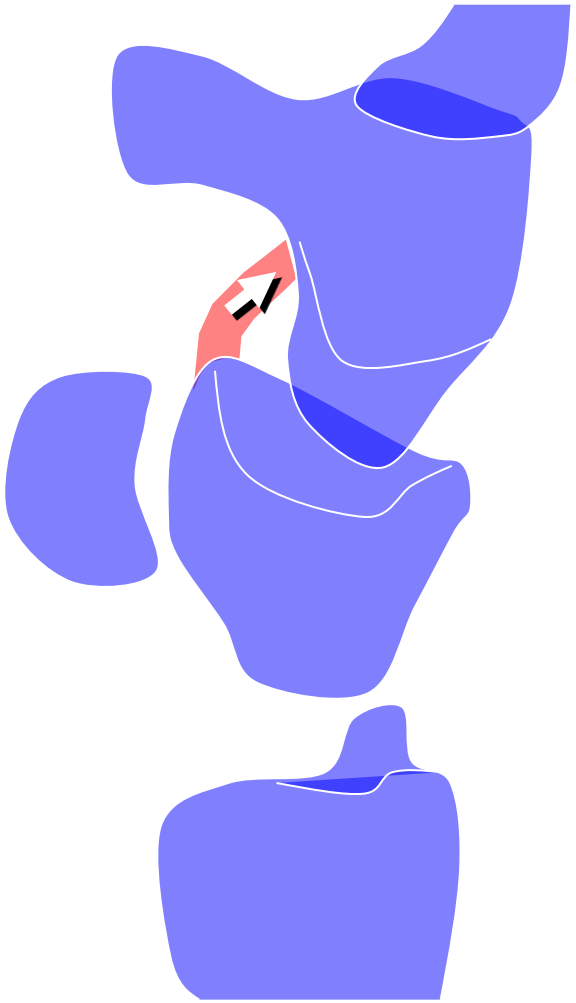
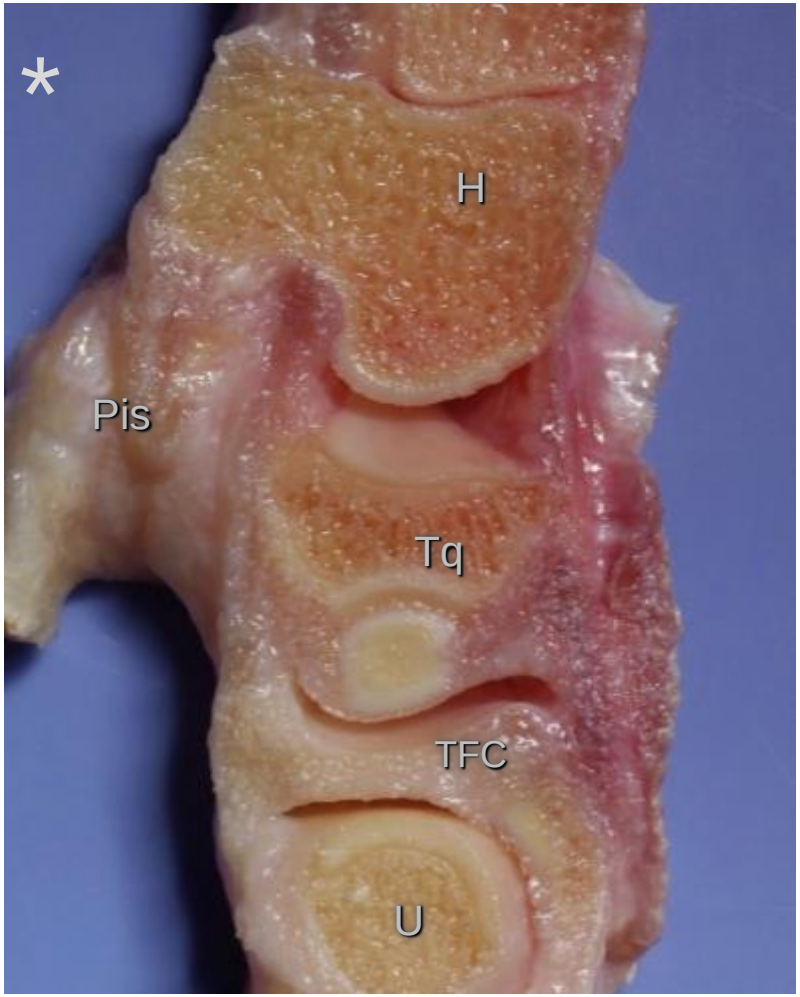
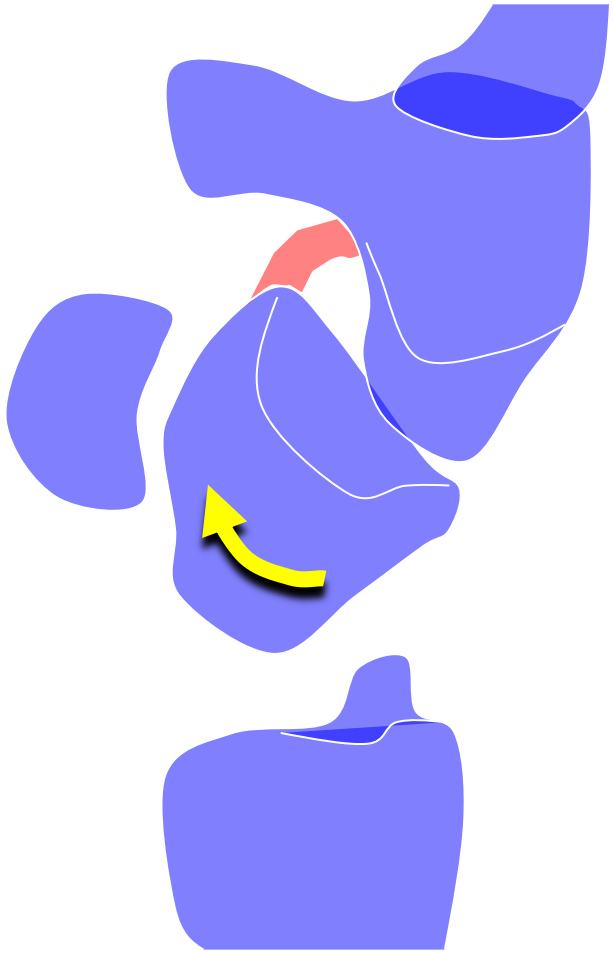




Under load, the scaphoid flexes, but the triquetrum extends





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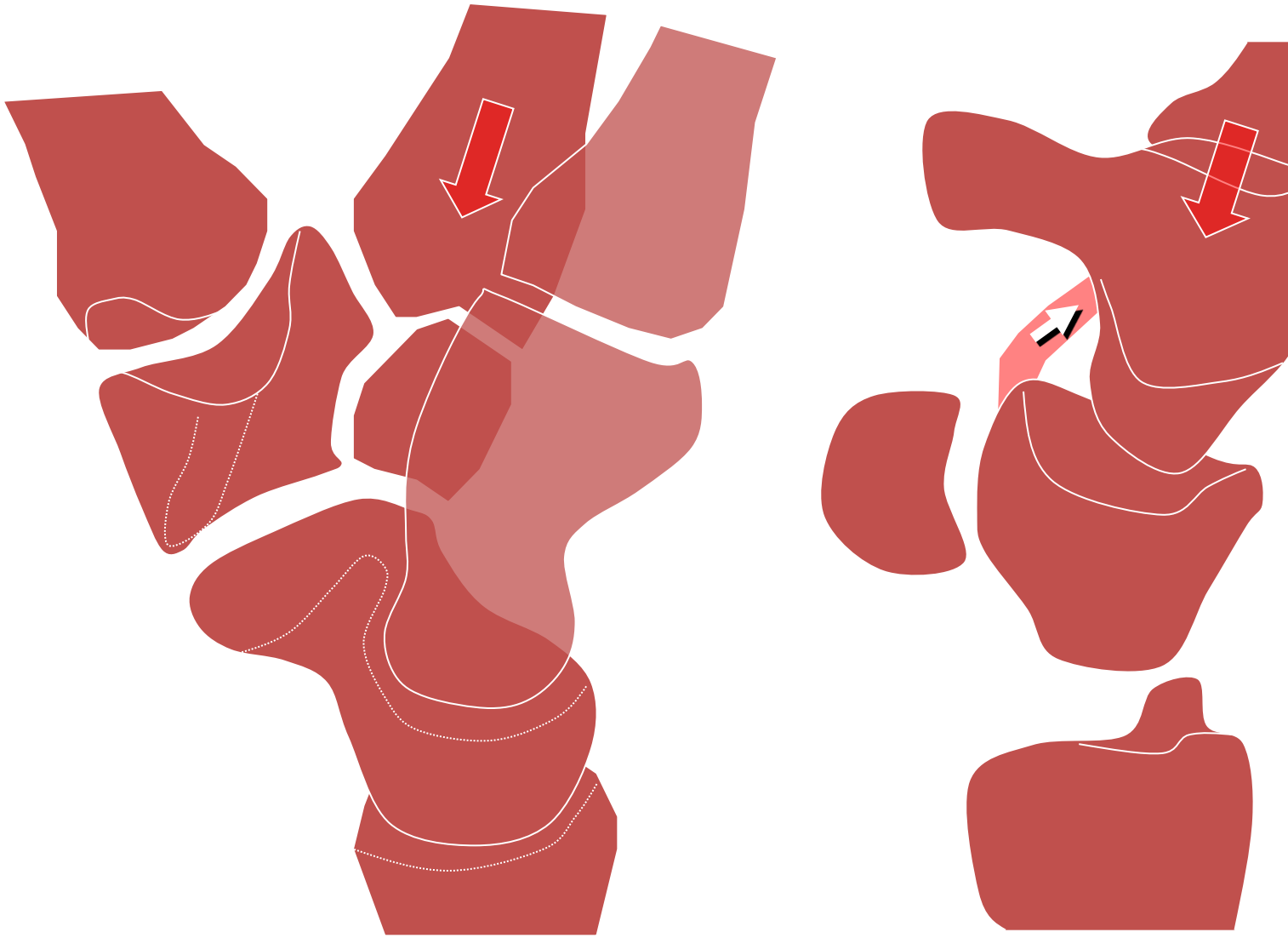
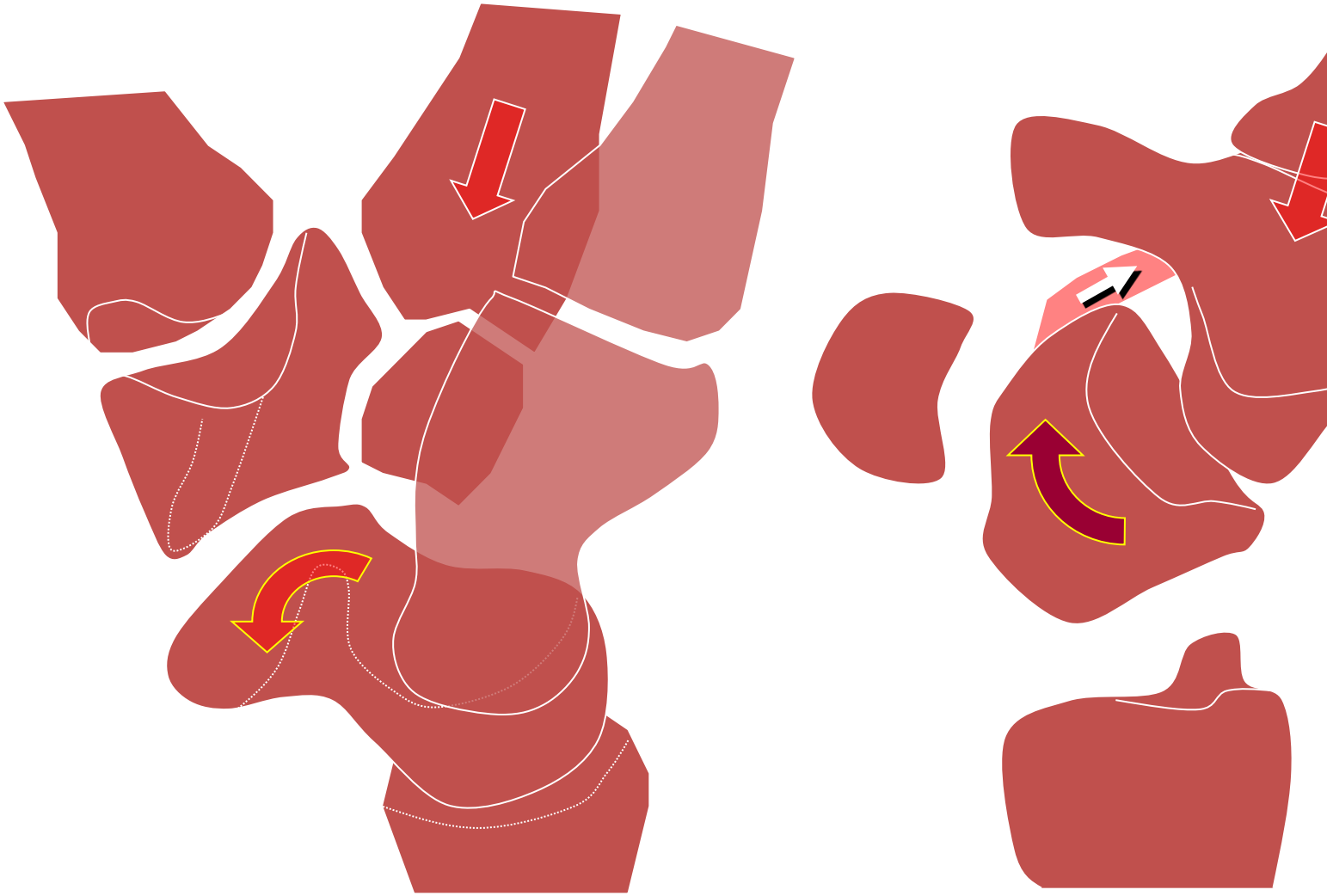
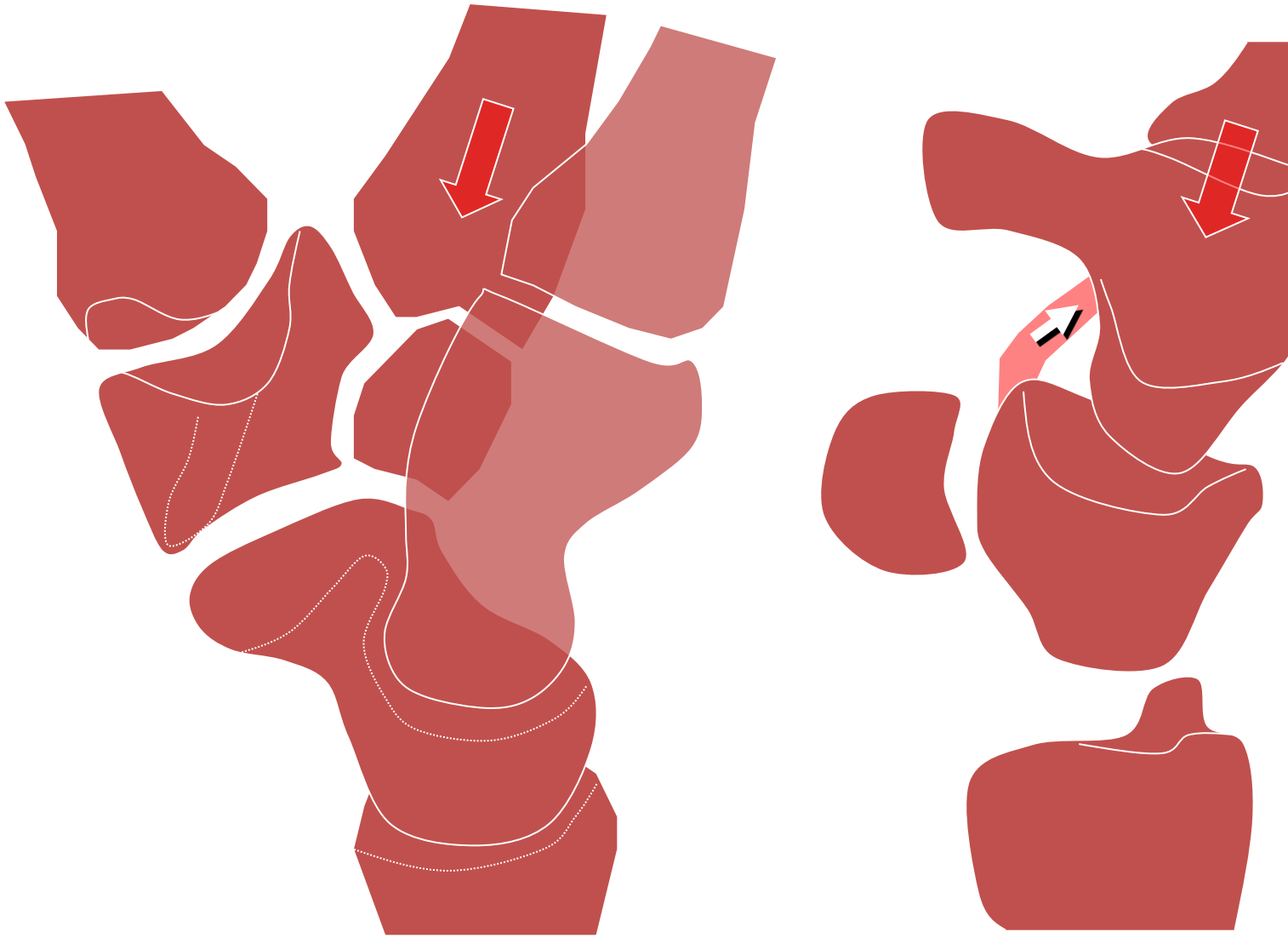


Scaphoid
flexion

Triquetrum
extension


Scaphoid
flexion
Triquetrum
extension



Scaphoid
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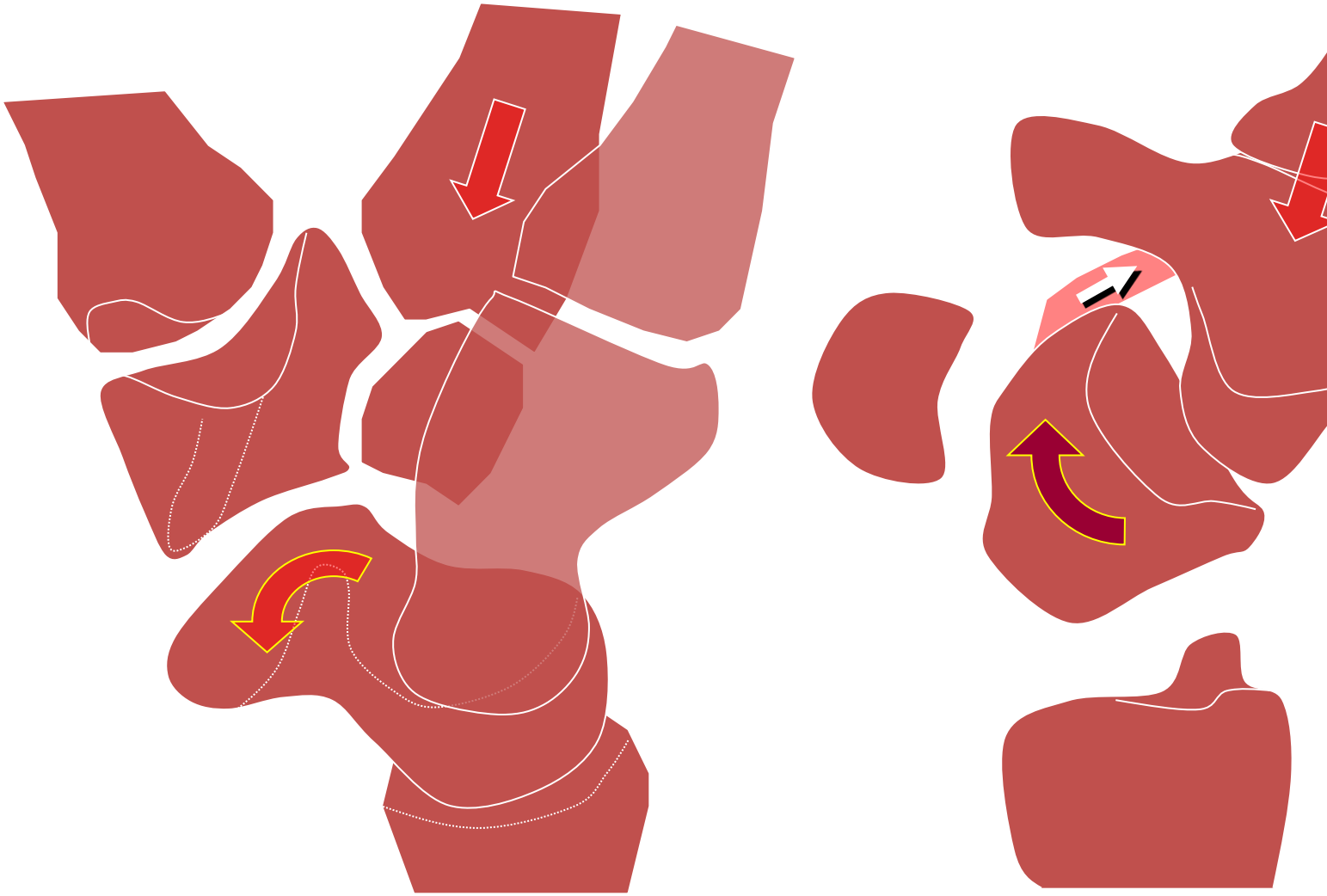
Scaphoid
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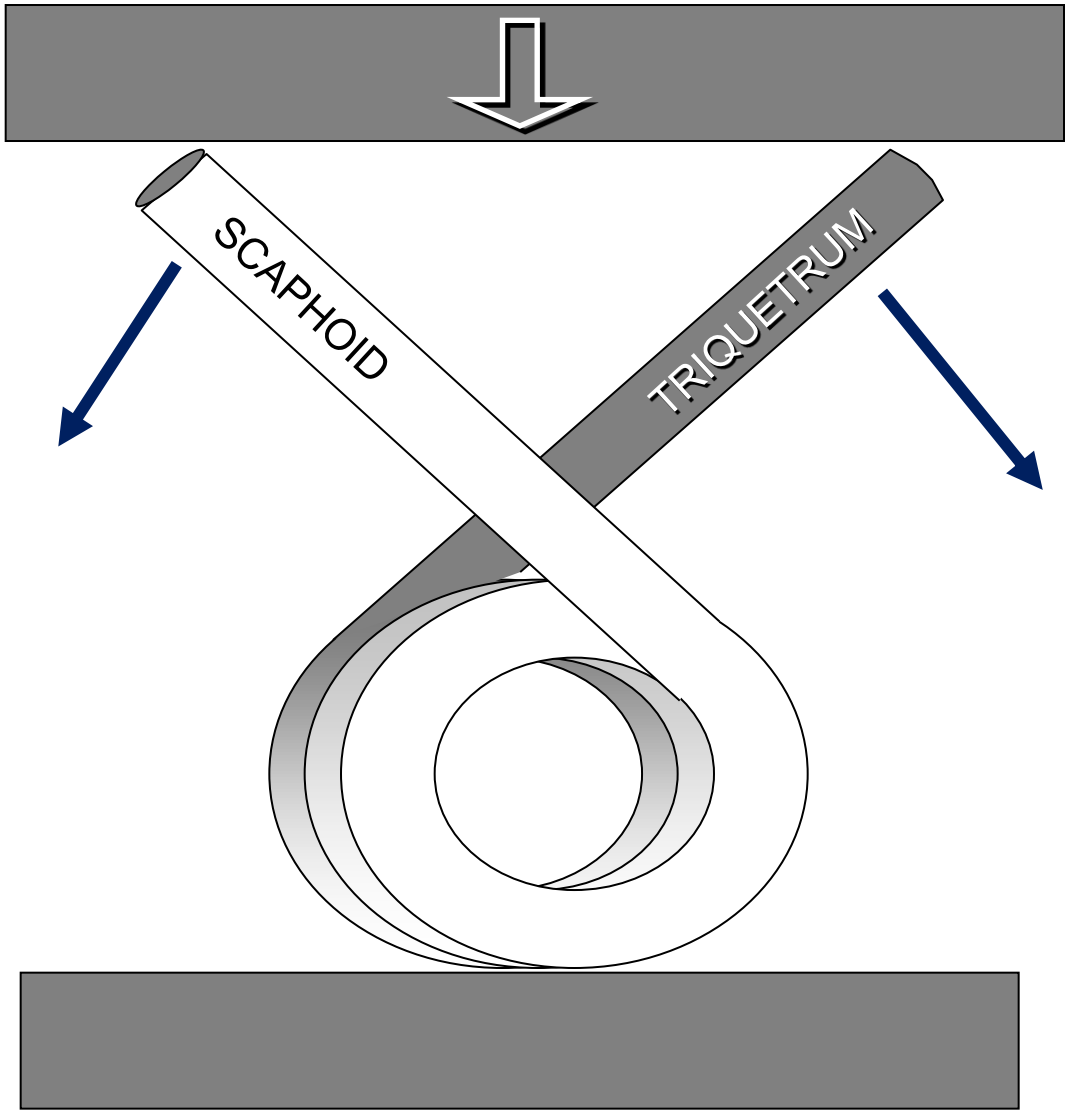
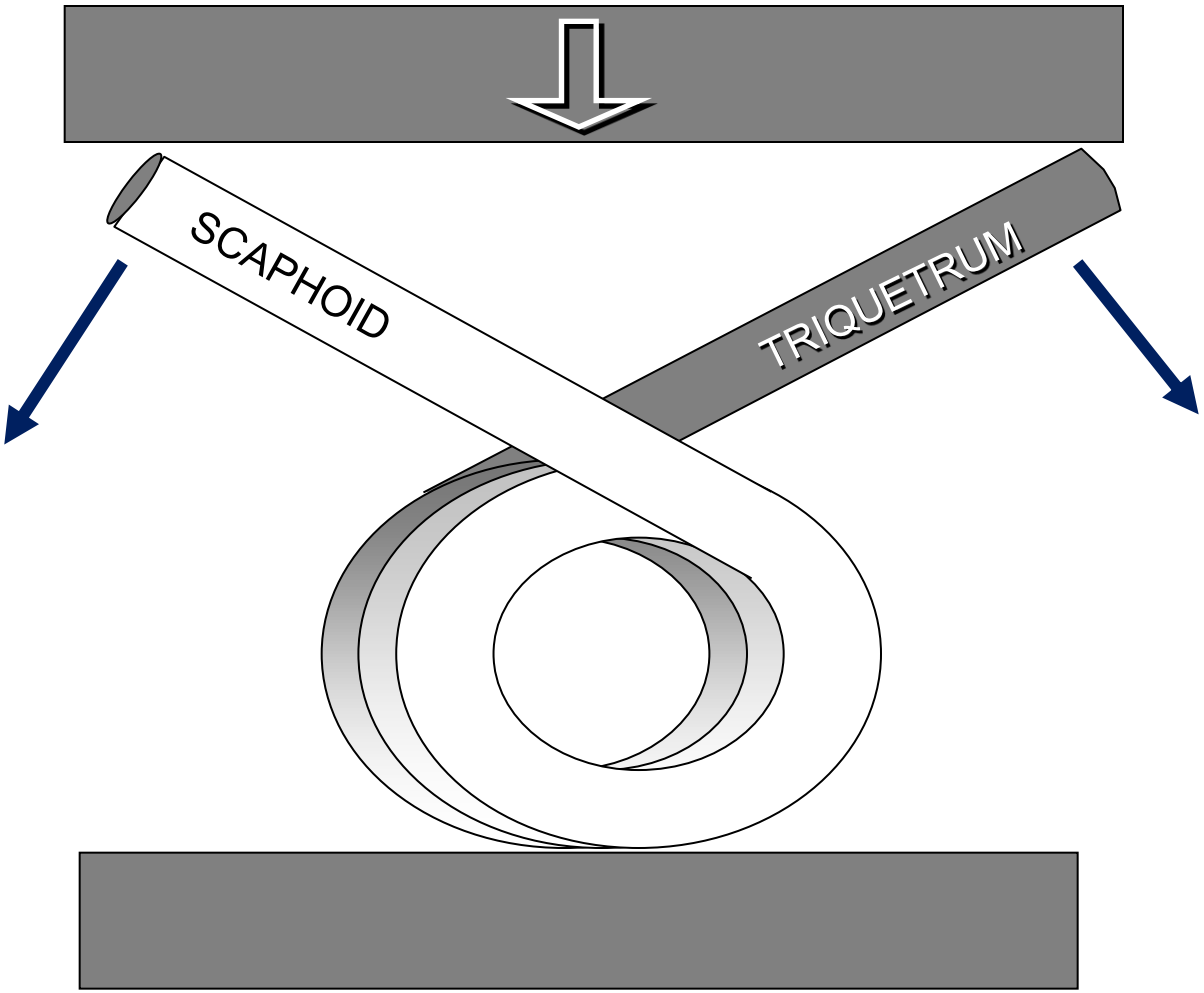

SCAPHOID
TRIQUETRUM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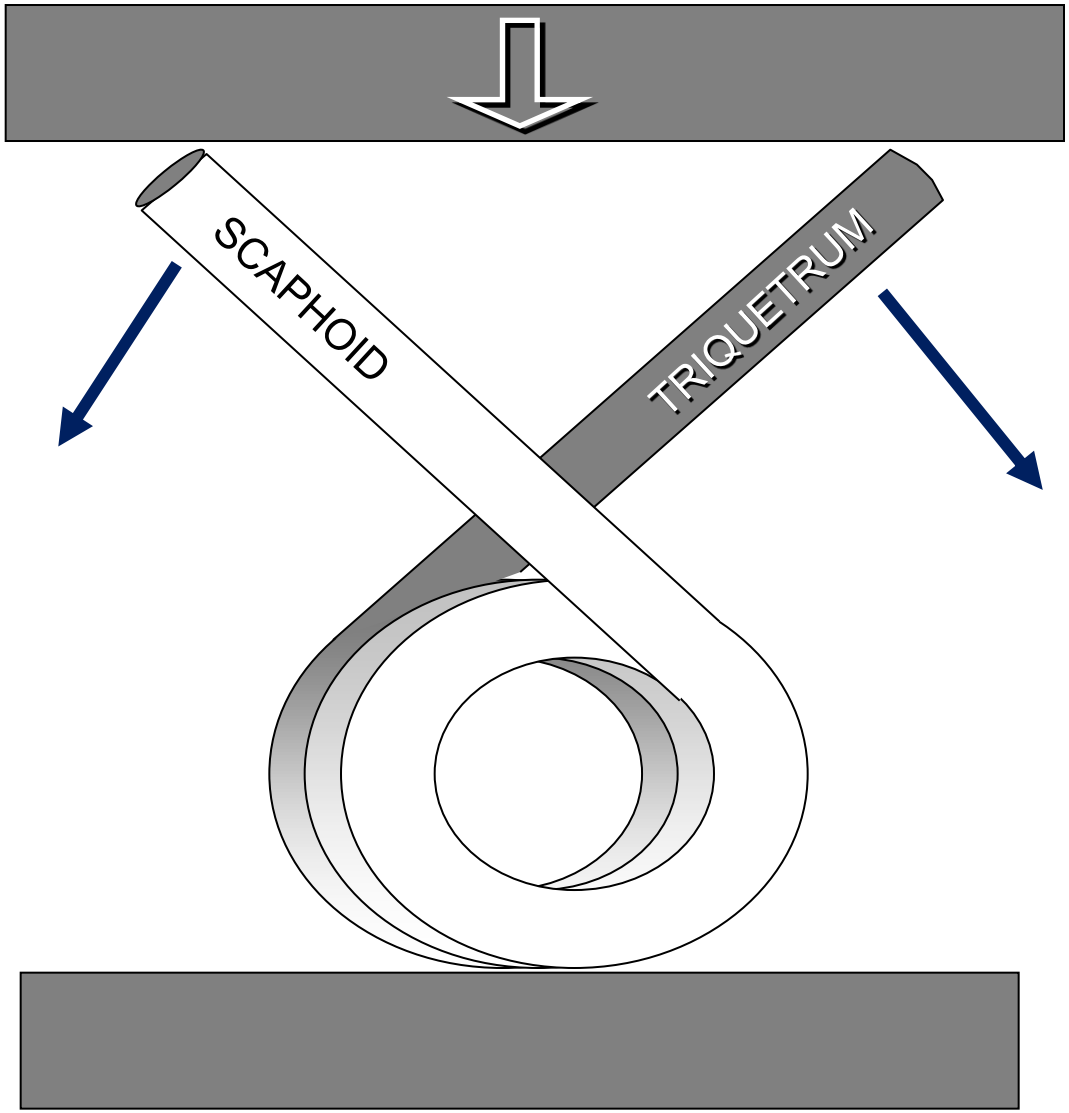
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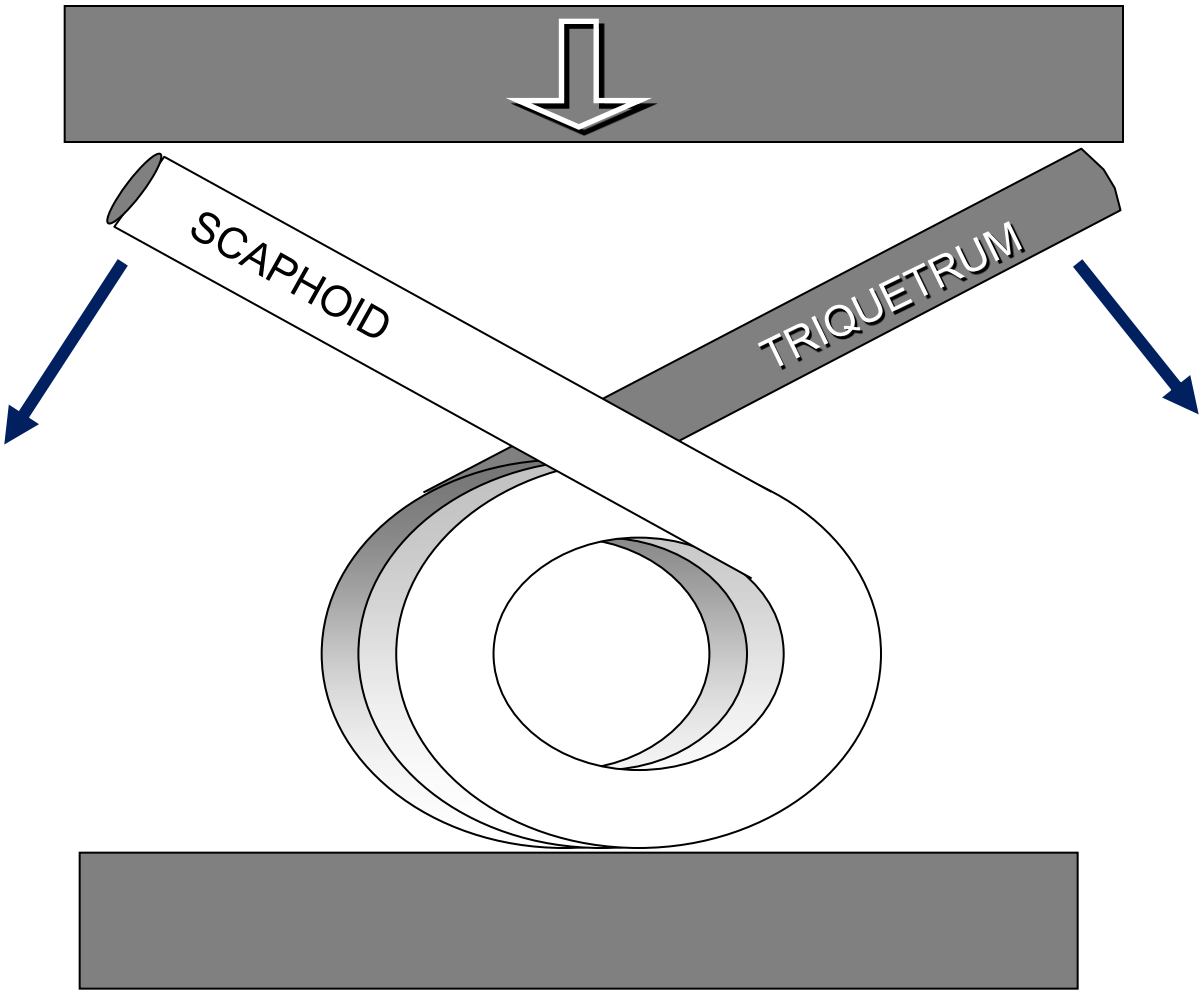
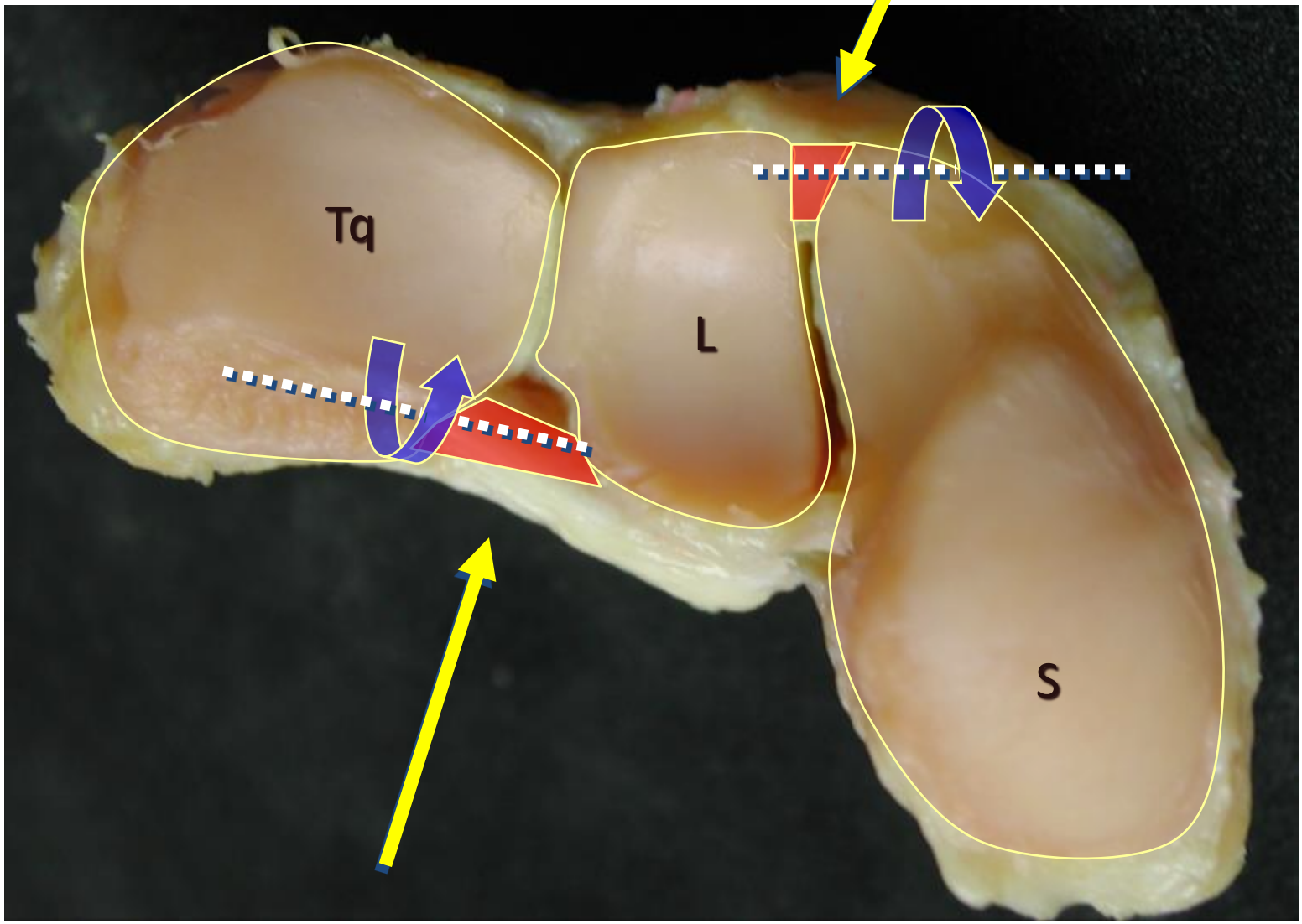

SCAPHOID
TRIQUETRUM

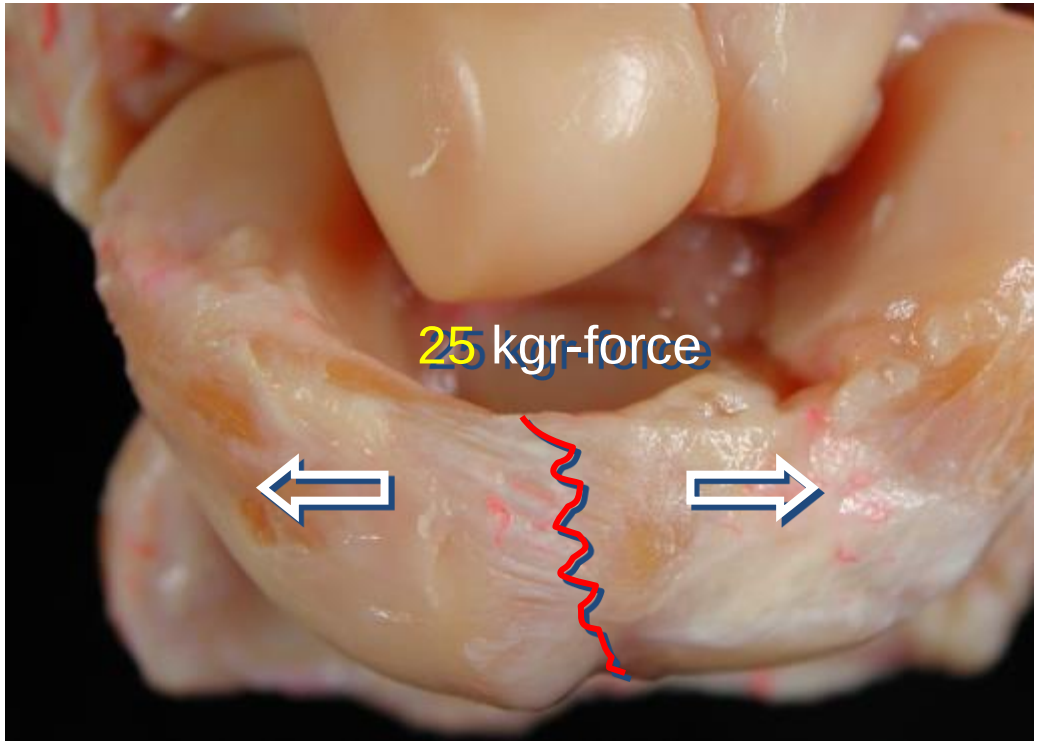
Shock-absorbers system

Dorsal SL ligament



Palmar LTq ligament


Are ligaments the only carpal stabilizers ?

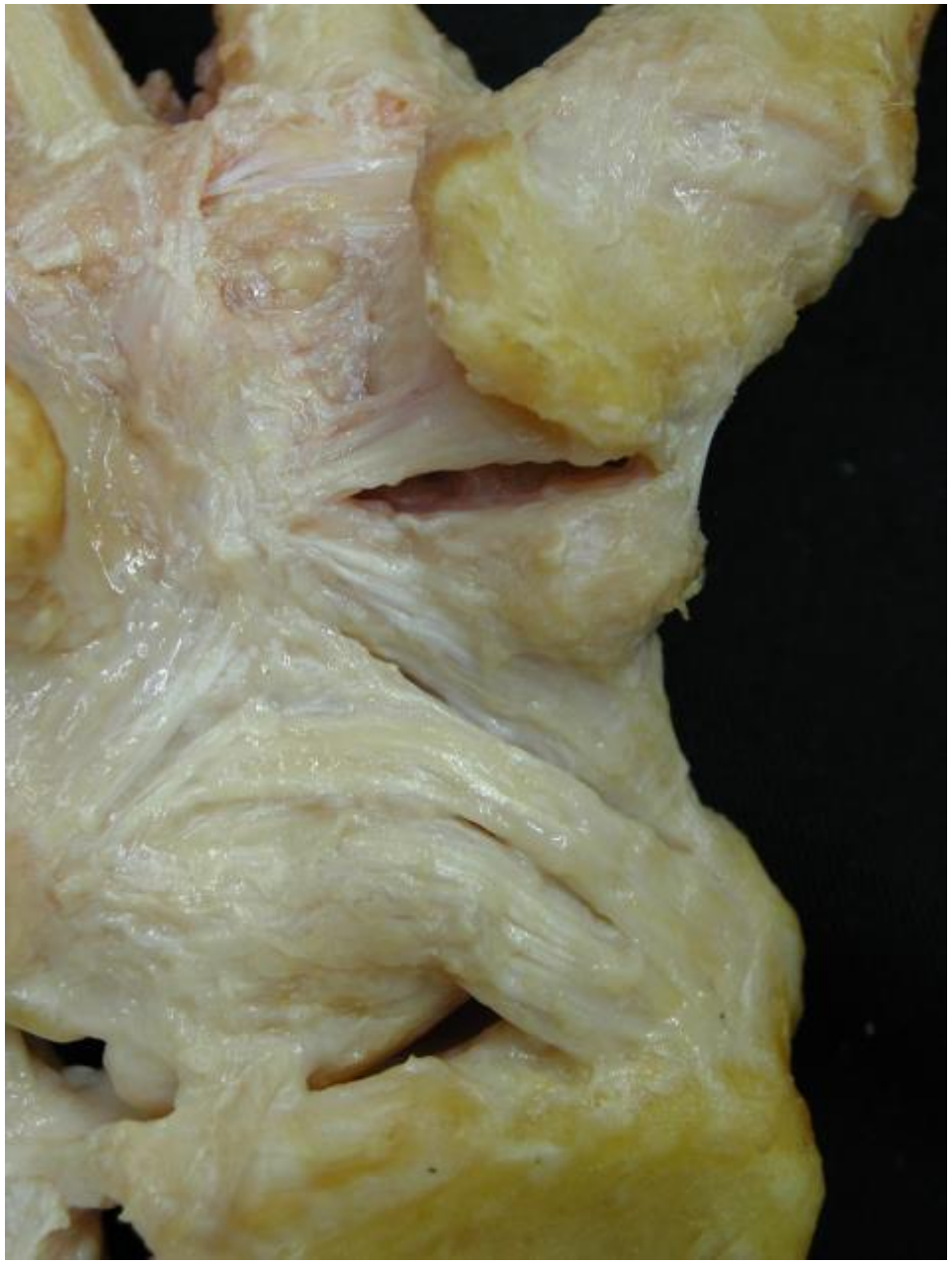


Average yield strength of the dorsal Scapholunate ligament: 260 Newtons

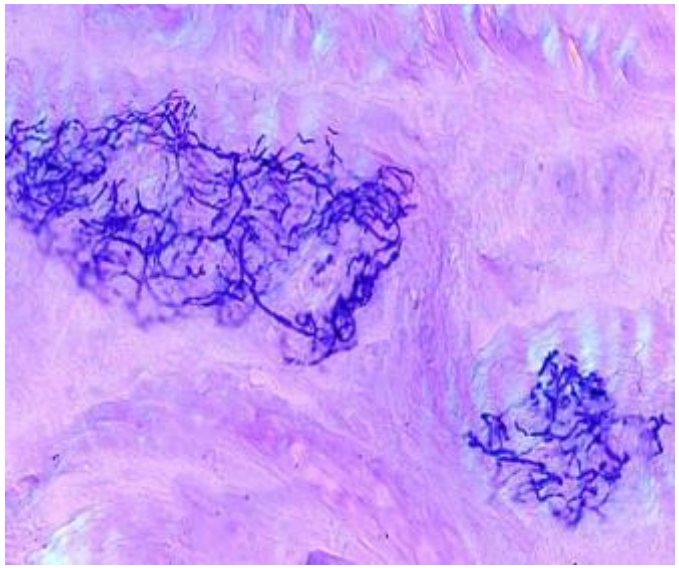
Berger et al. J Hand Surg 24A:953-962, 1999

Axial loading of the wrist

Wrist can resist much more force



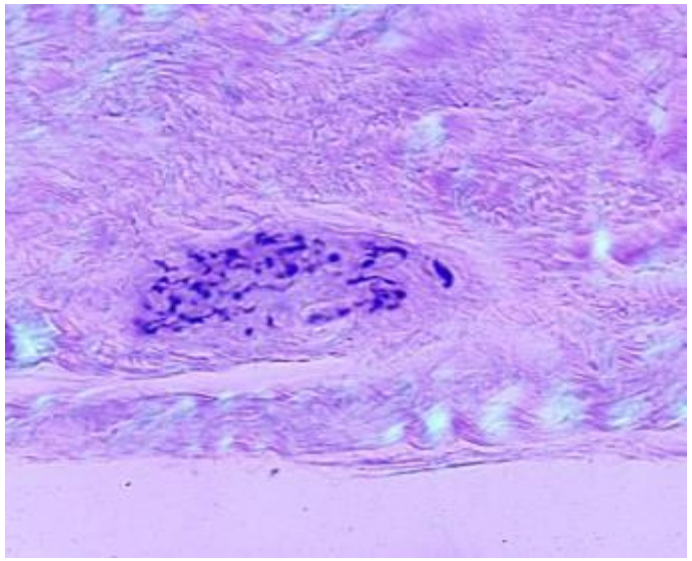
Ligaments are not stiff cables aimed to resist tension...



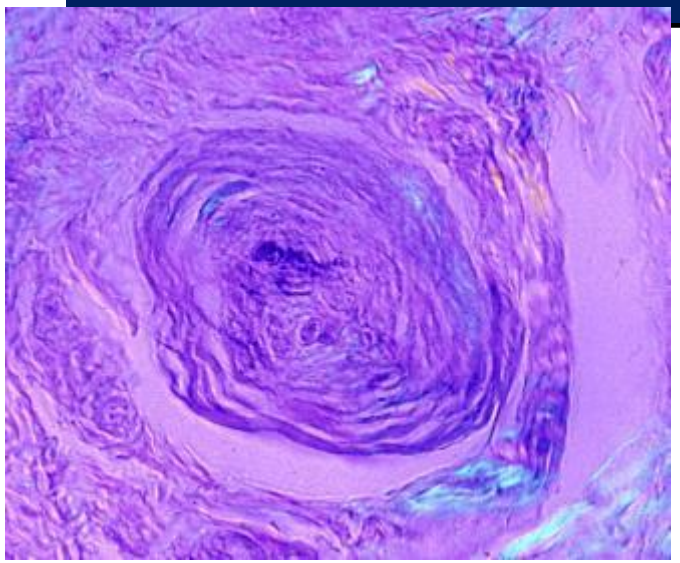
Golgi

Ligaments are not stiff cables aimed to resist tension...

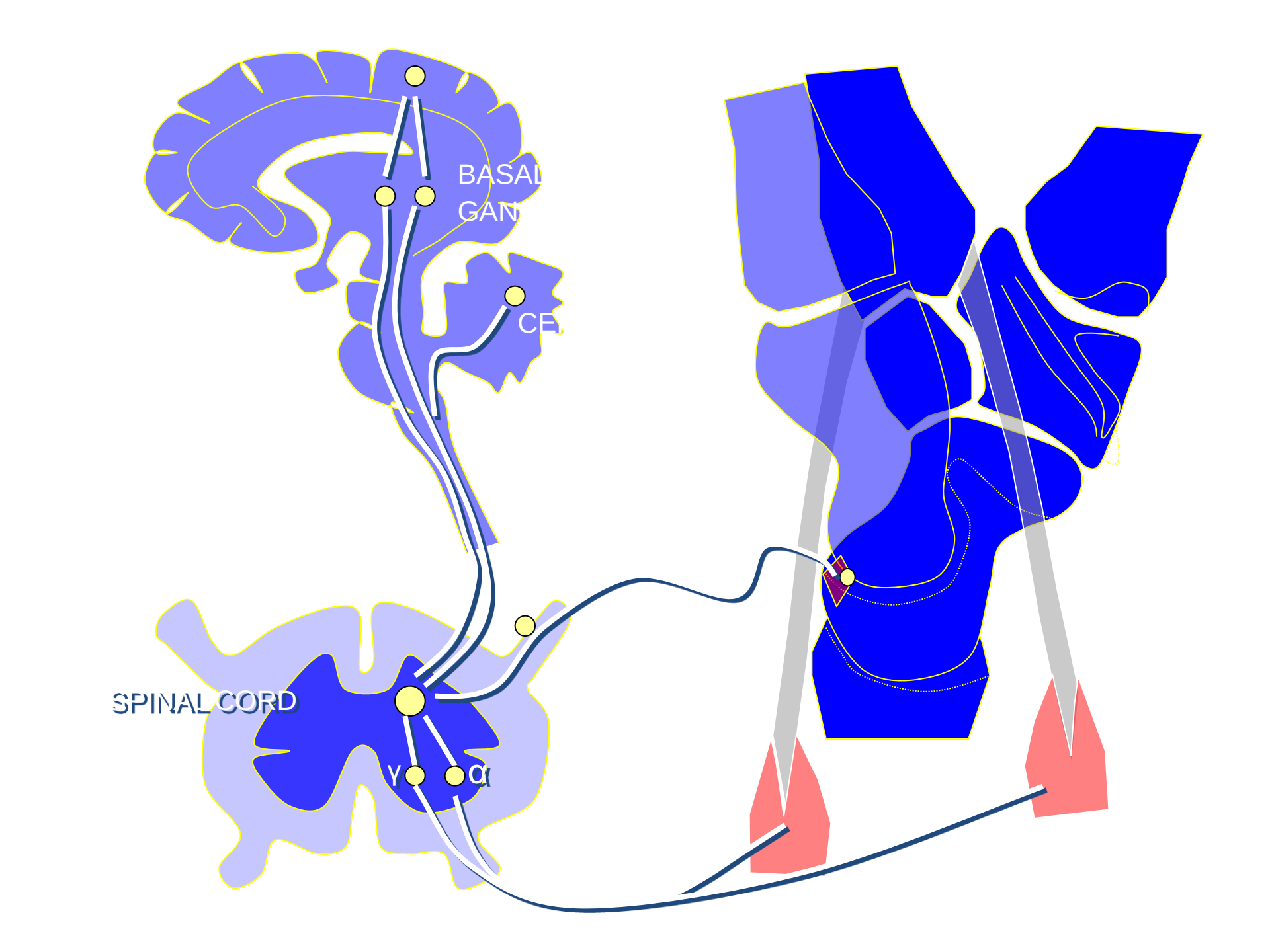
...but complex structures containing mechanoreceptors

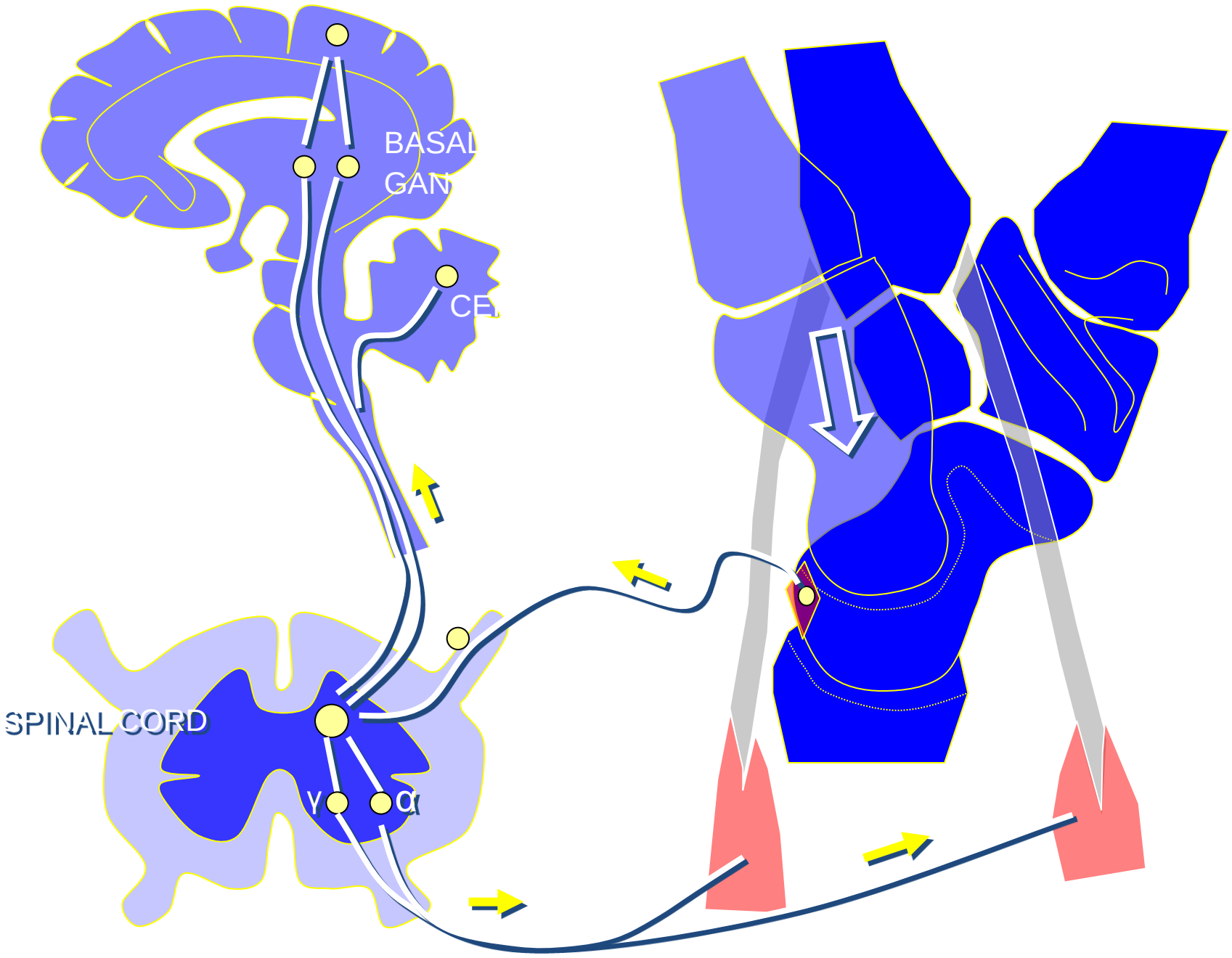


Ruffini



Pacinian


BASAL
GAN
CE
SPINAL CORD
V
C


BASAL
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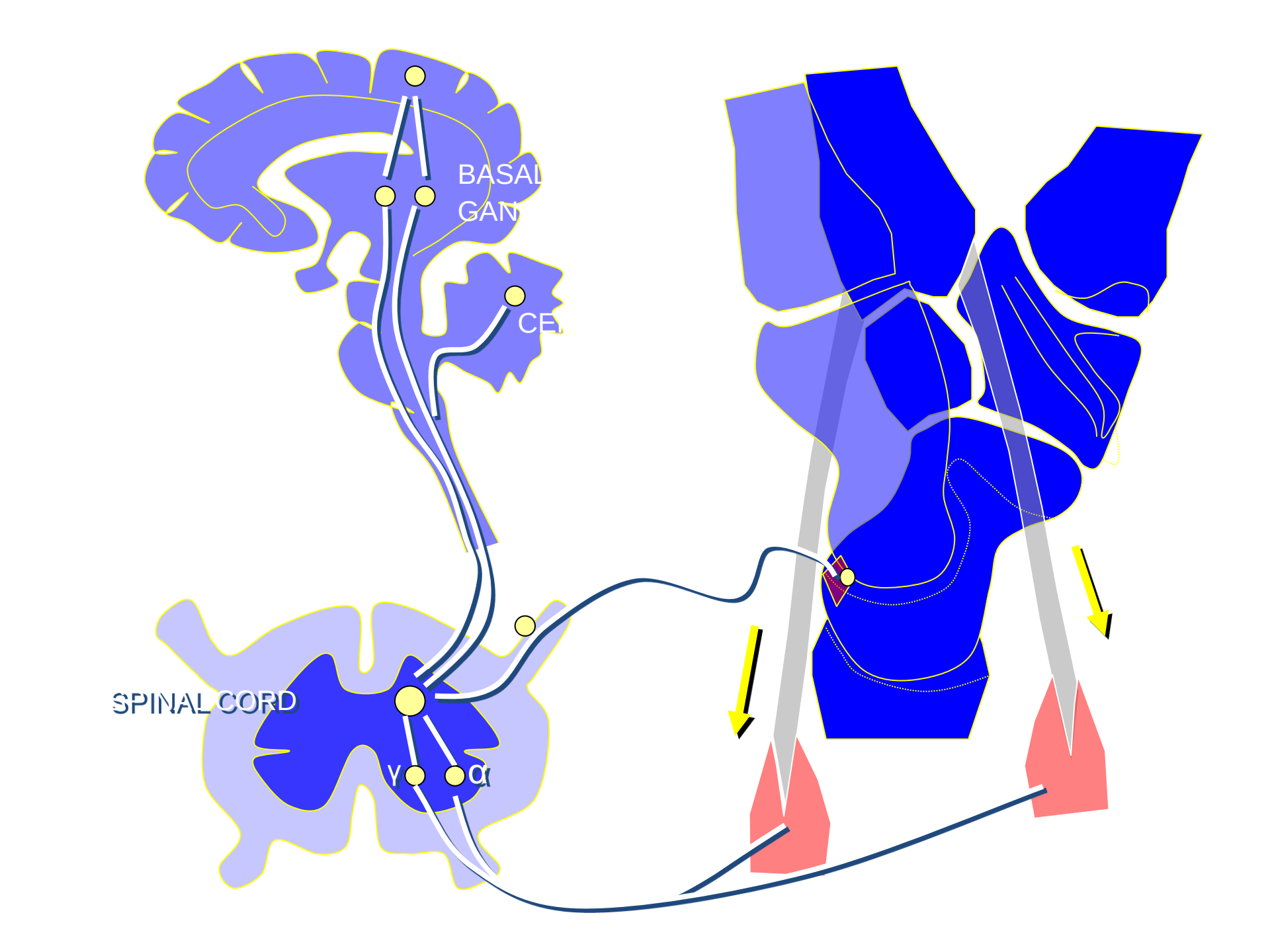
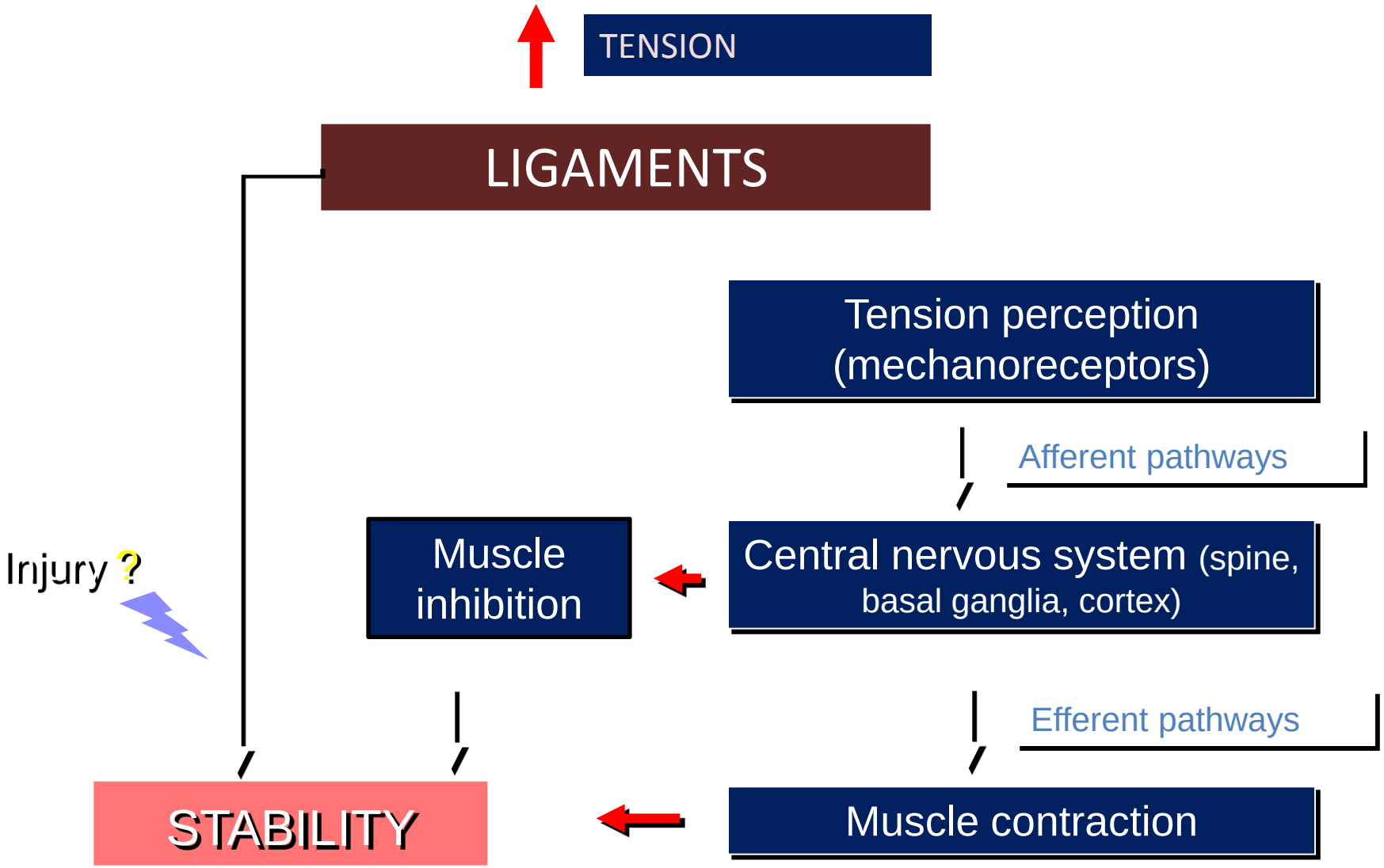
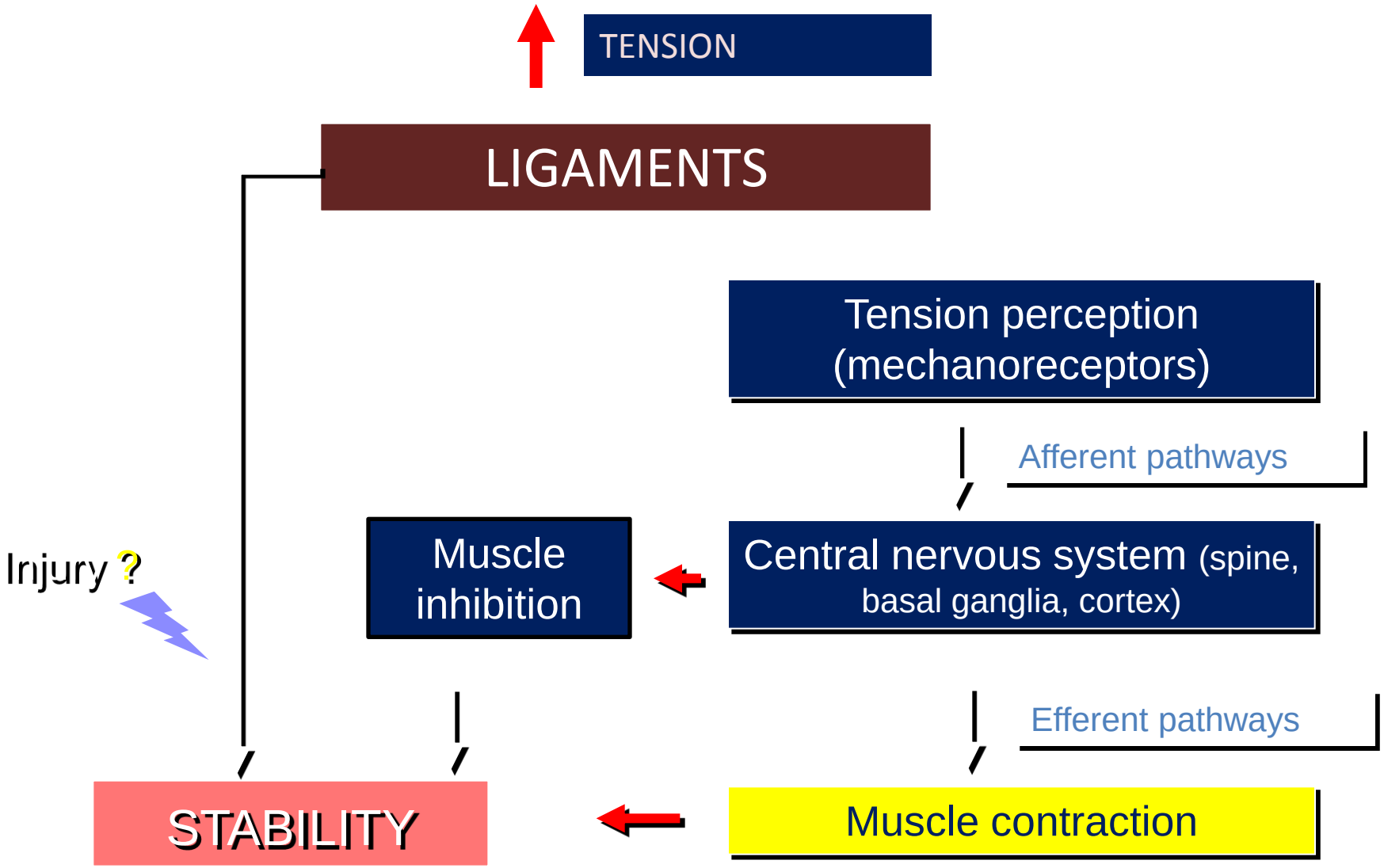
SPINAL CORD


BASAL
GAN
CE
SPINAL CORD
Y
α

The latest in wrist biomechanics

- From a kinematic point of view, the midcarpal joint is more important than the radiocarpal joint
- There are different patterns of wrist motion
- Loads across the carpus are much higher than previously assumed
- Ligaments are sensory structures with an important proprioceptive role in carpal stability
- **Muscles are the ultimate stabilizers of the wrist**


TENSION
LIGAMENTS
Tension perception (mechanoreceptors)
Afferent pathways
Injury ?
Muscle inhibition
Central nervous system (spine, basal ganglia, cortex)
Efferent pathways
STABILITY
Muscle contraction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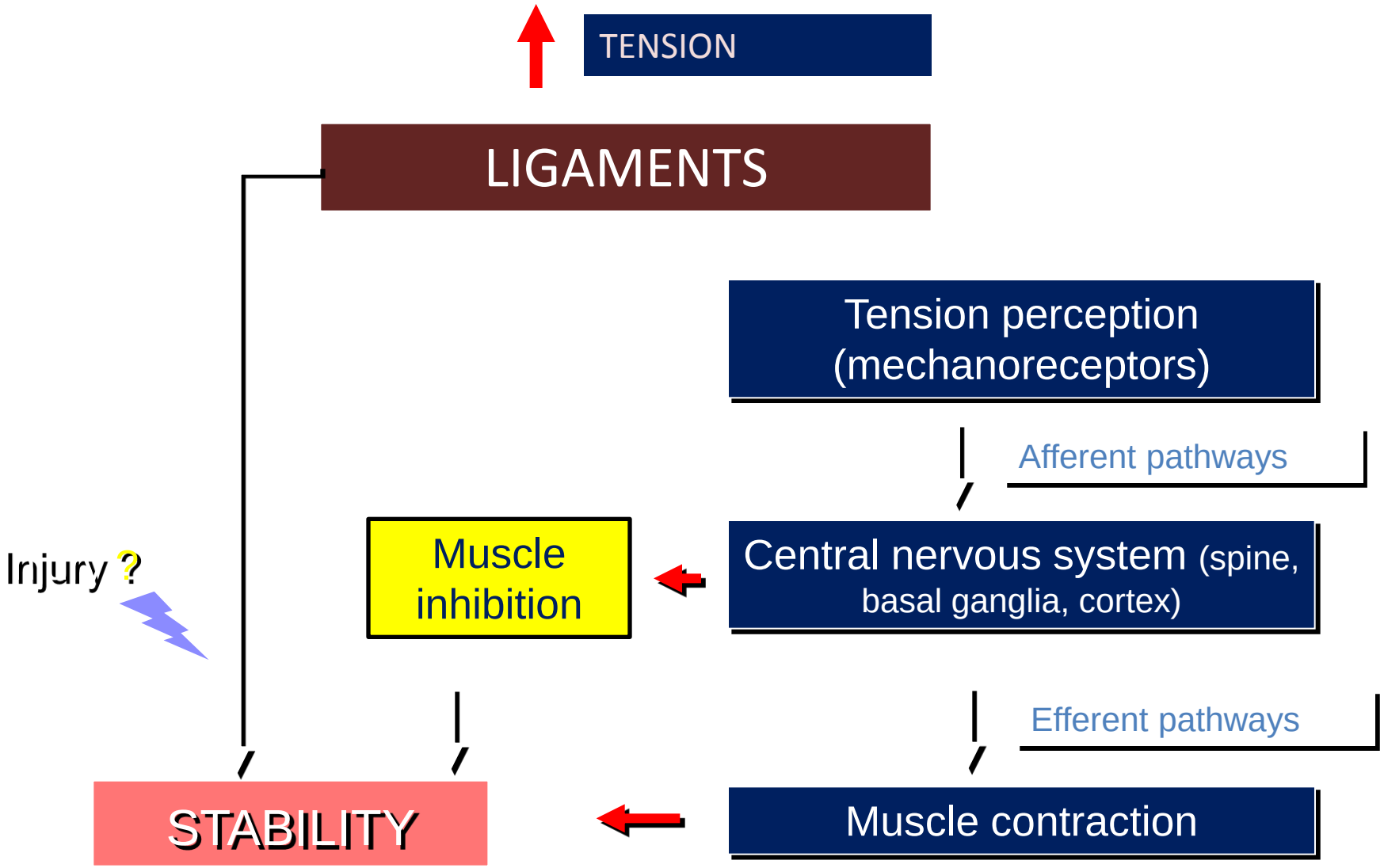
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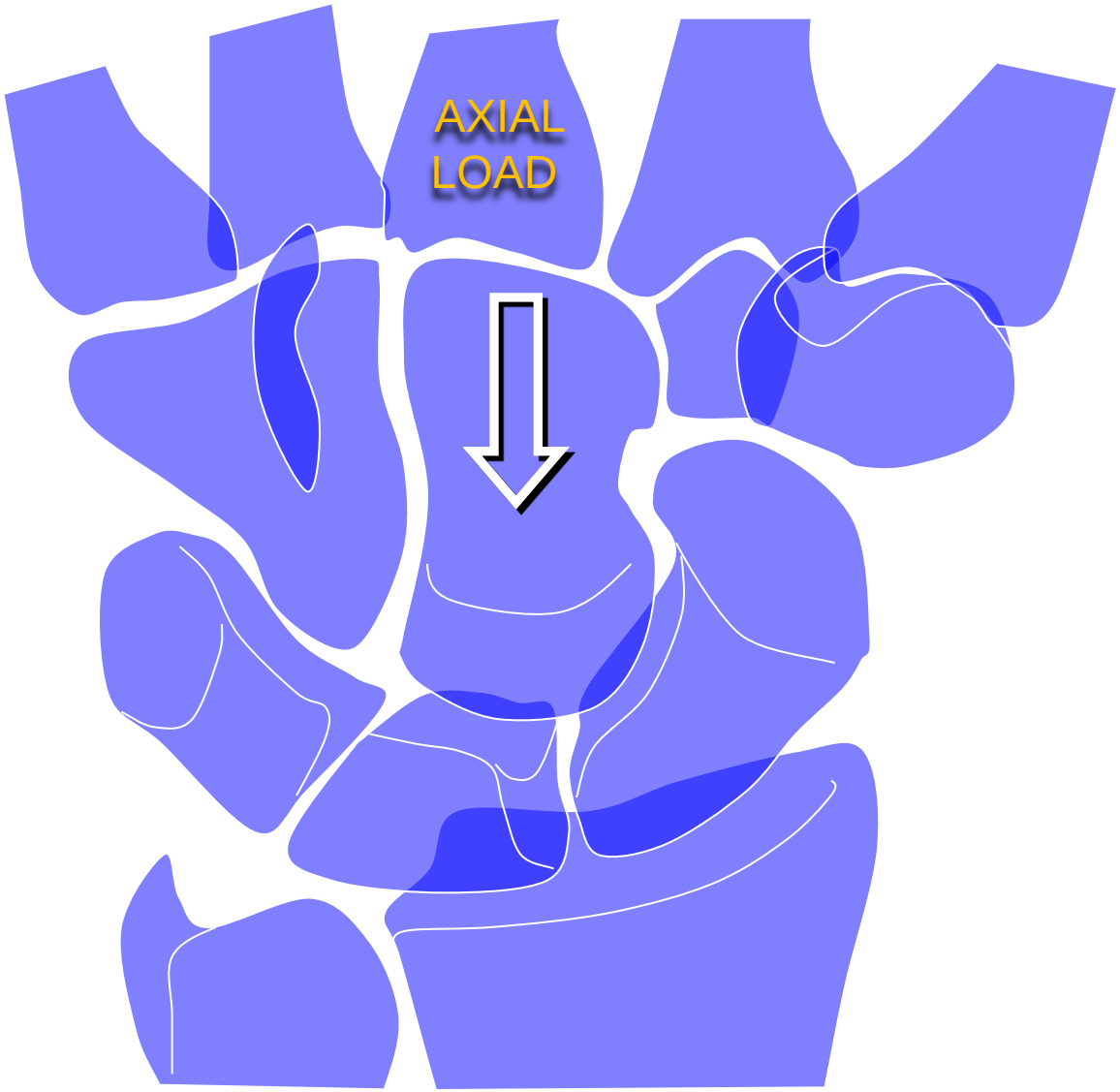
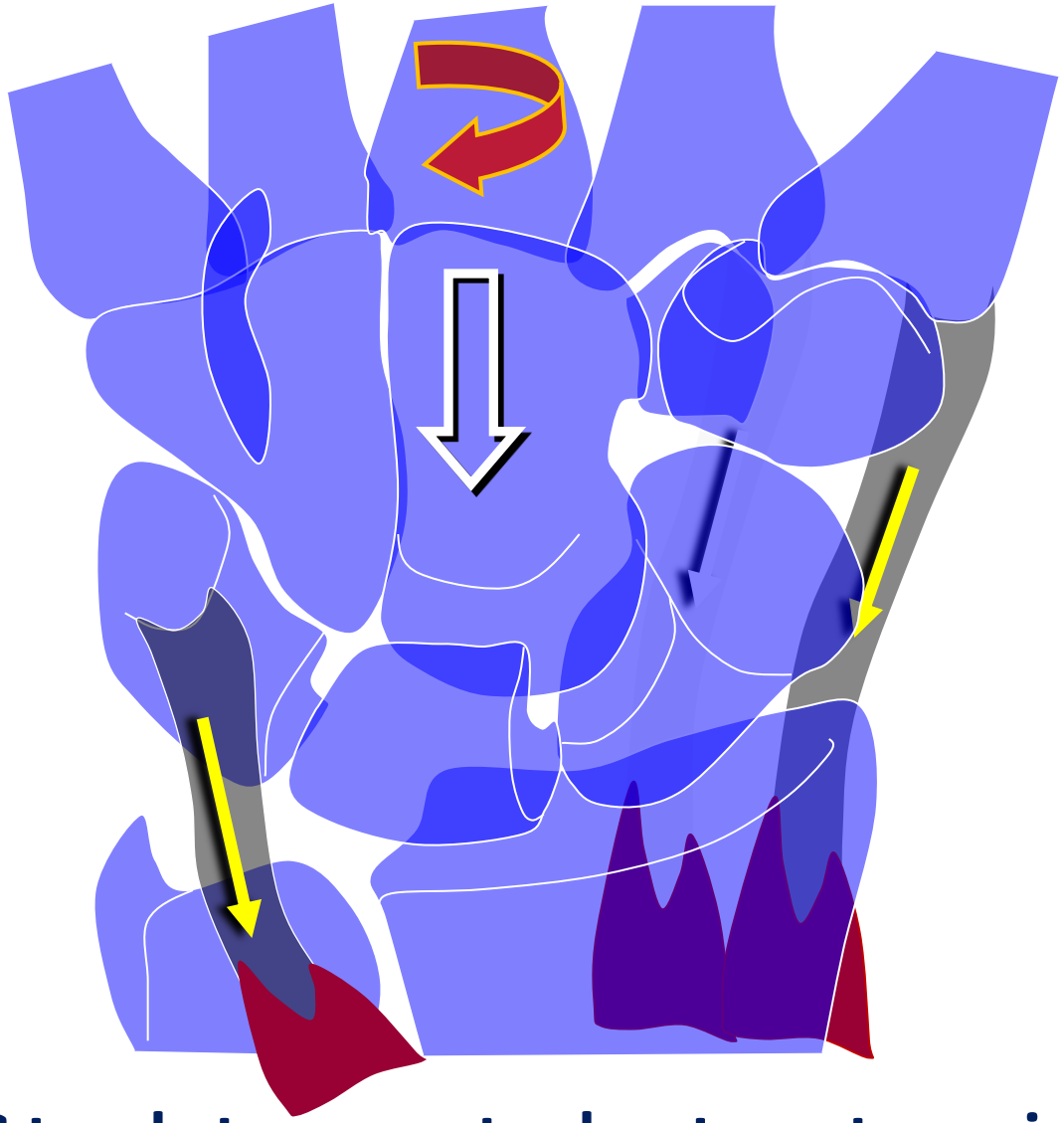
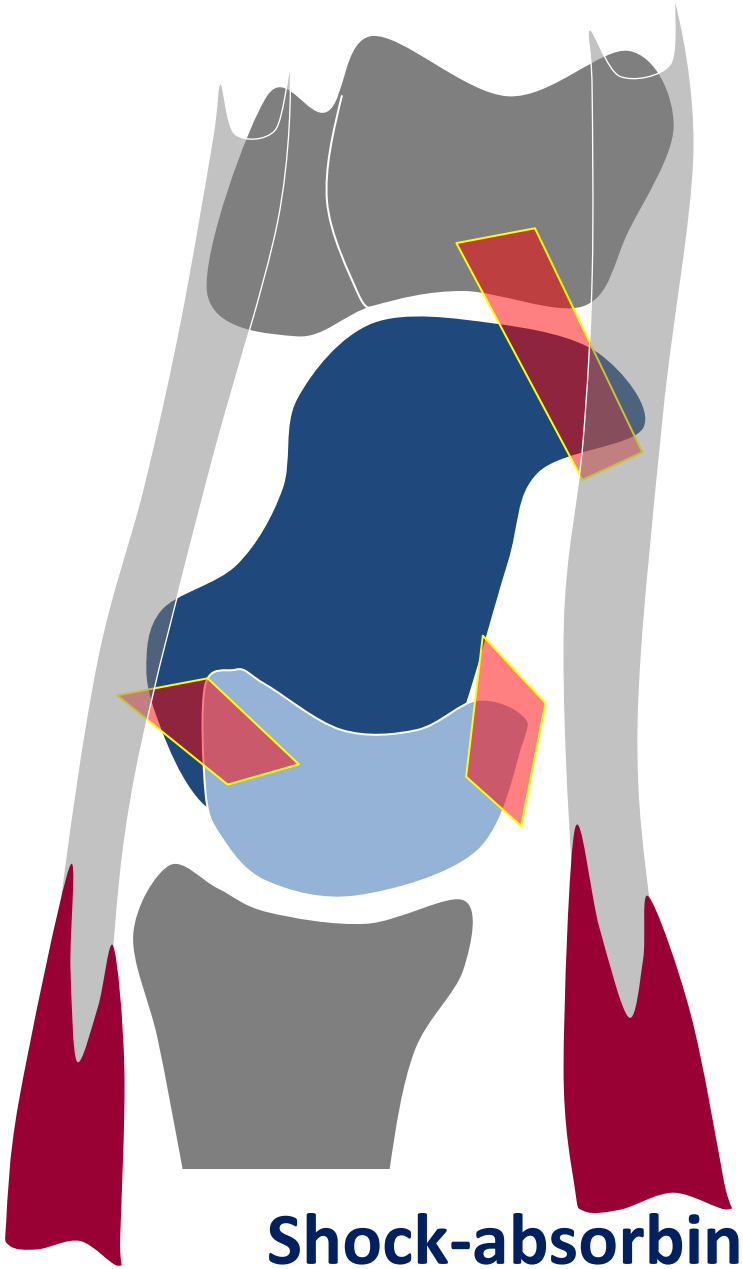

AXIAL
LOAD

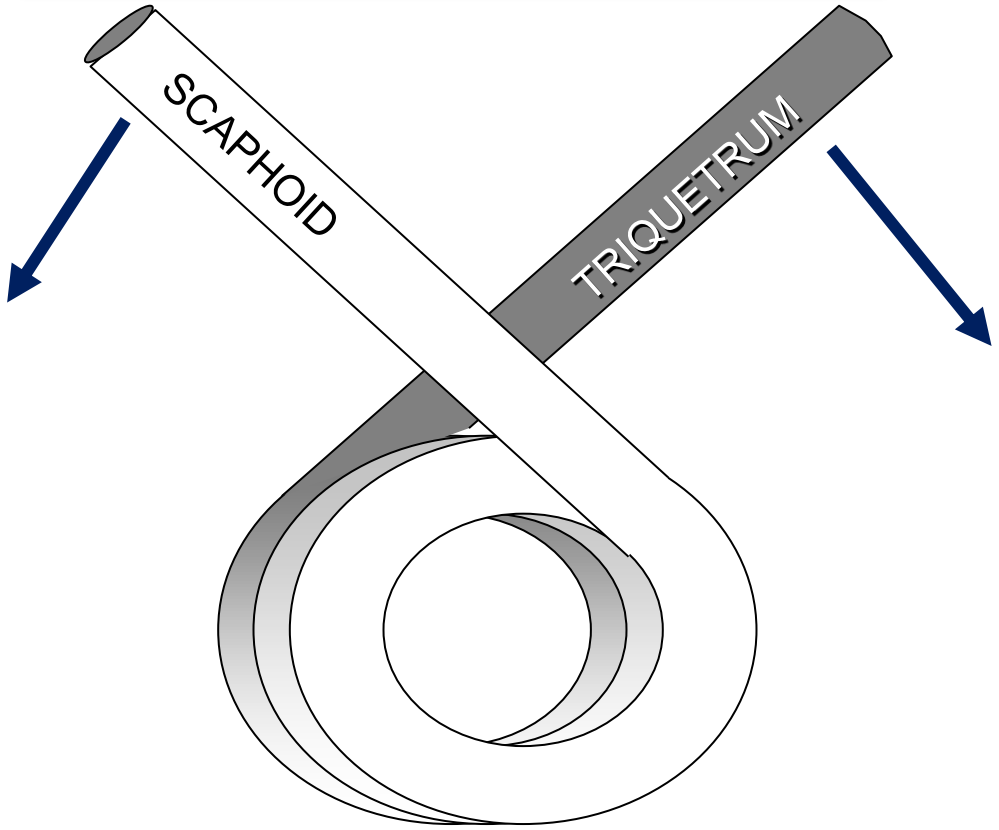
Pronation



MC tends to pronate due to antagonist's muscles



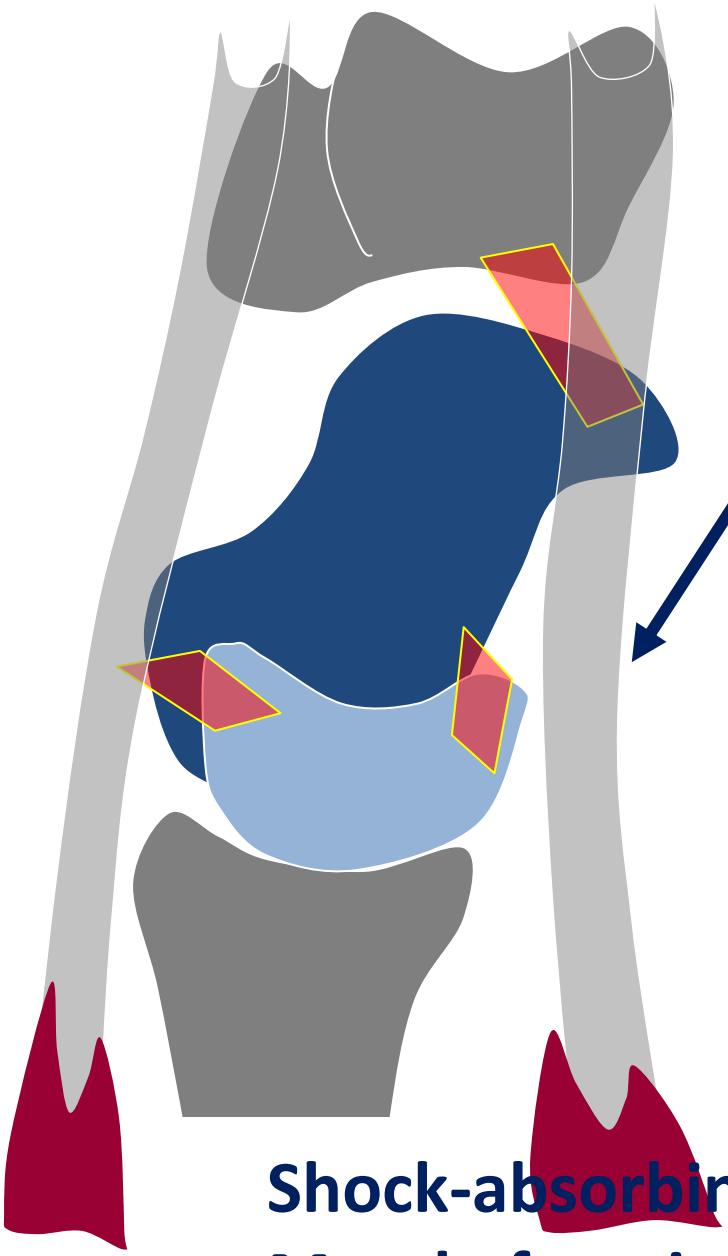
Force balance

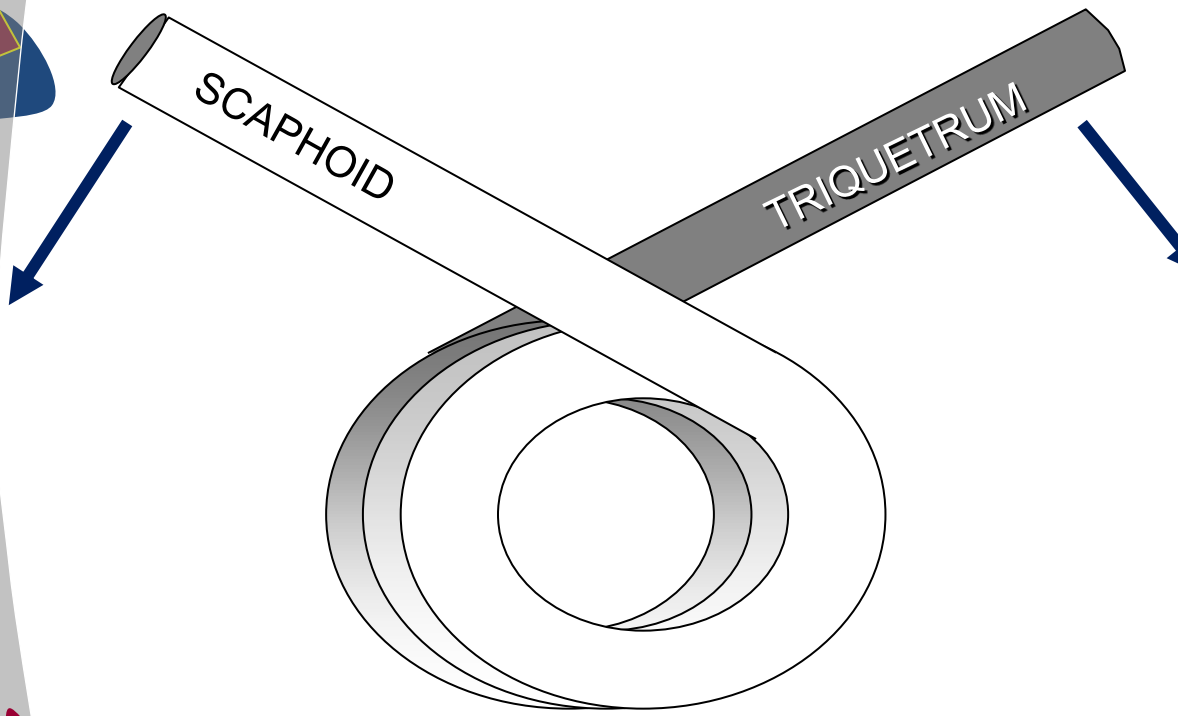


Shock-absorbing RC, ligaments, MC pronation

Muscle function

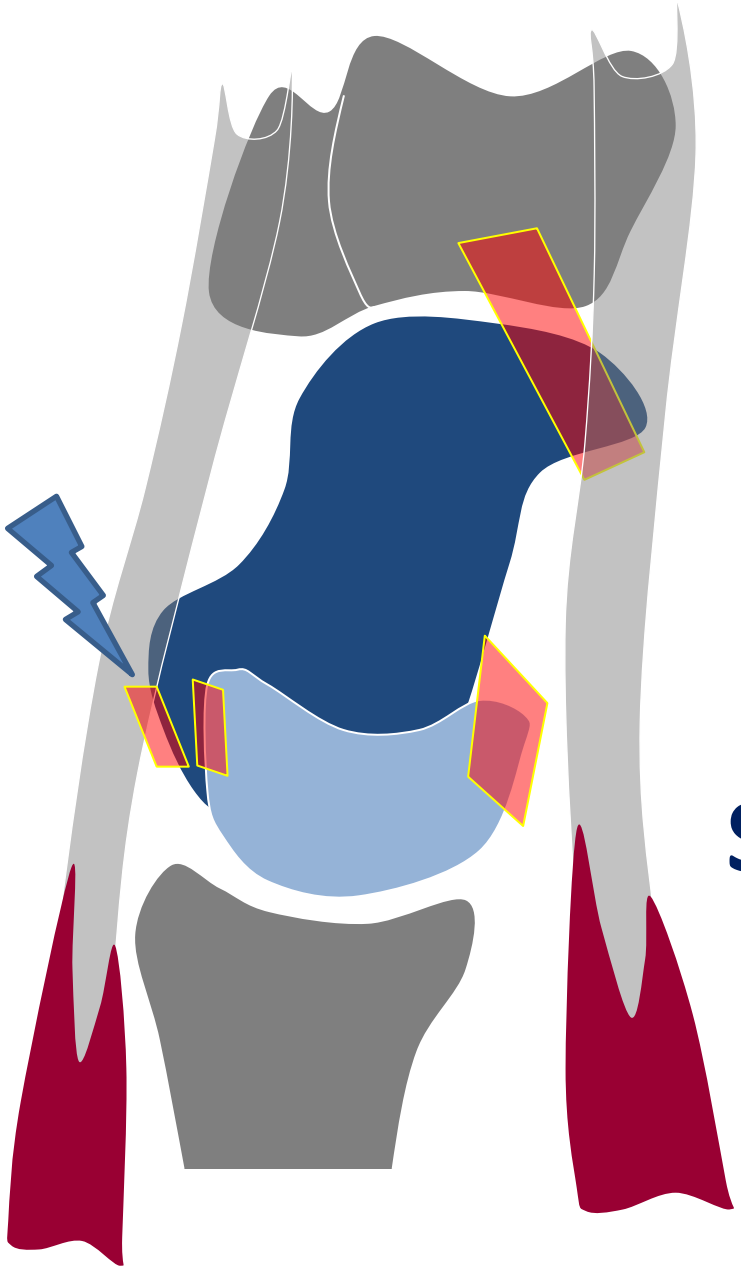
Force balance





Shock-absorbing RC, ligaments, MC pronation

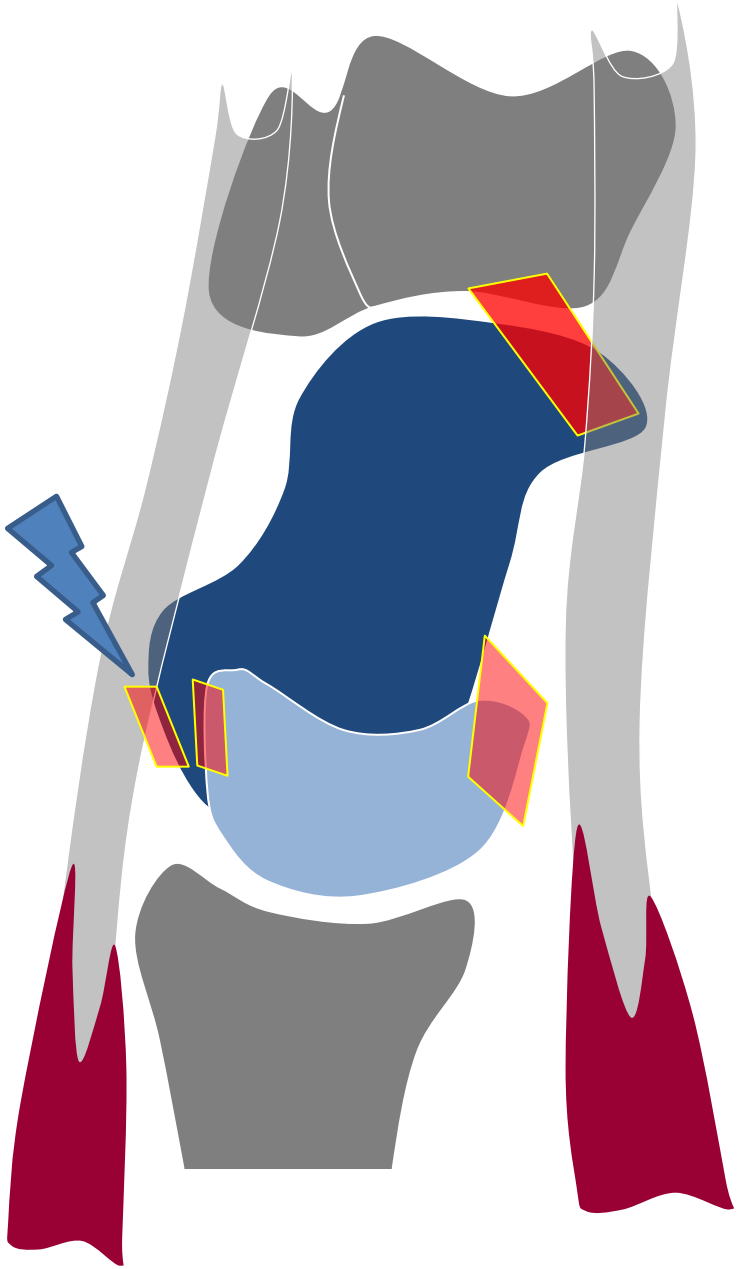
Muscle function



Force balance

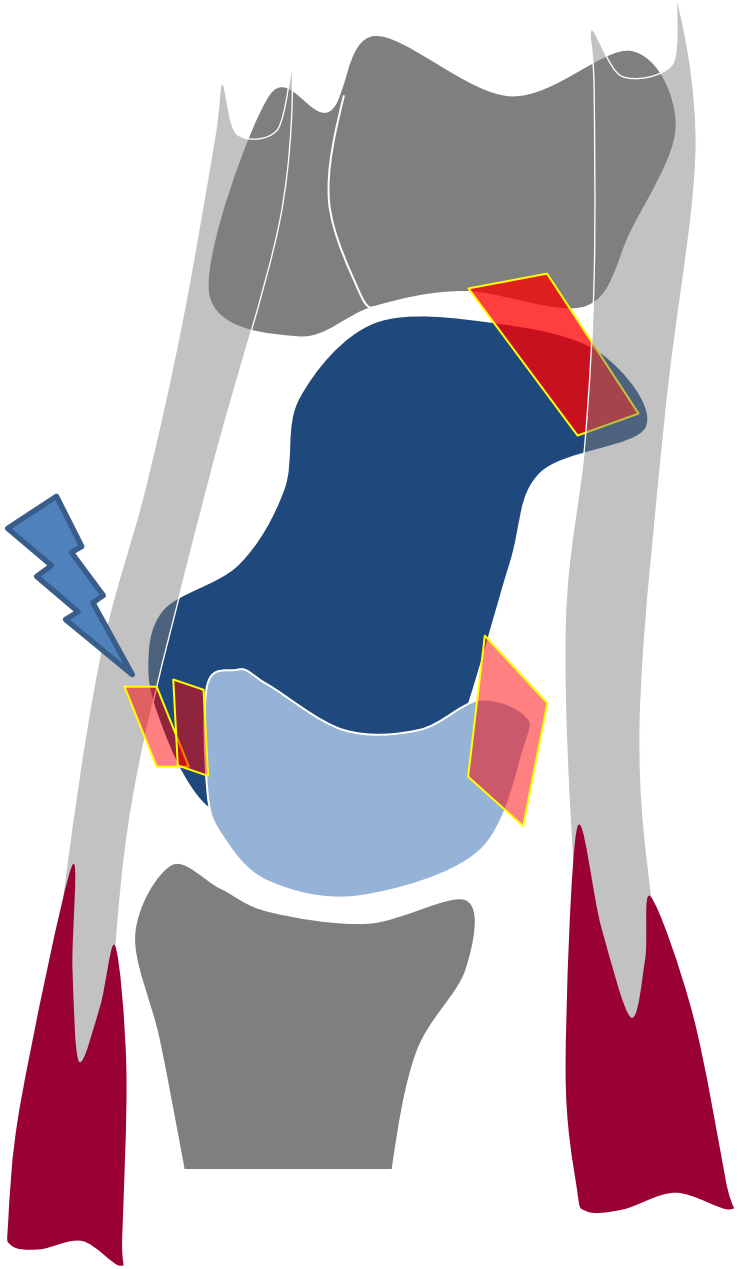
?

Scapho-lunate rupture



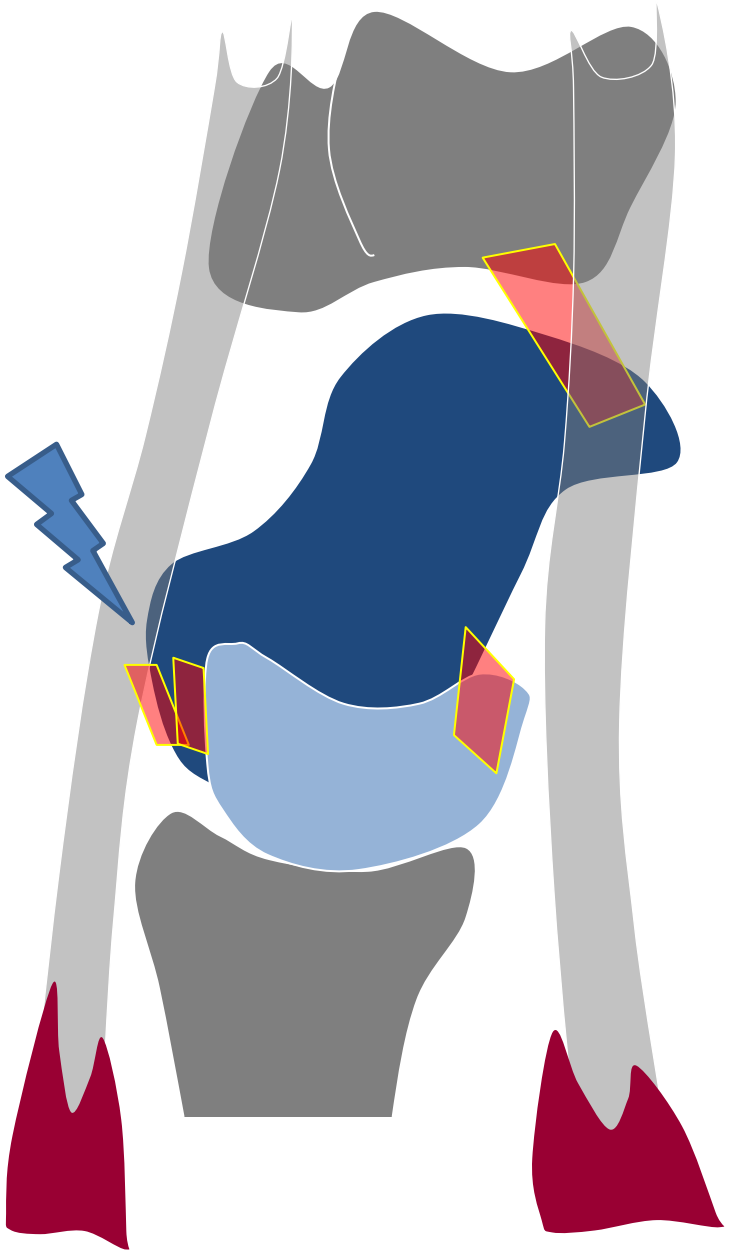
Force balance

- Instability goes in stages



Force balance

- **Stage I- pre-dynamic**
- Partial tear of SL
- Normal et rest and normal under load



Force balance

- **Stage I- pre-dynamic**
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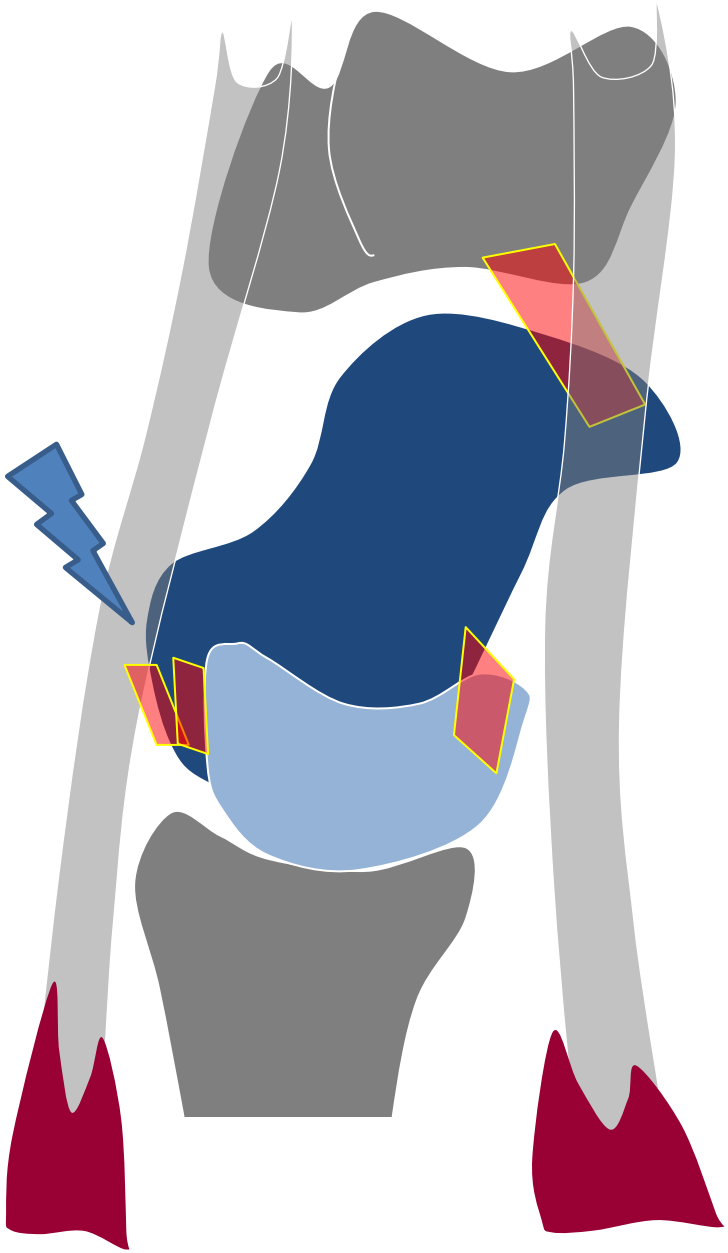
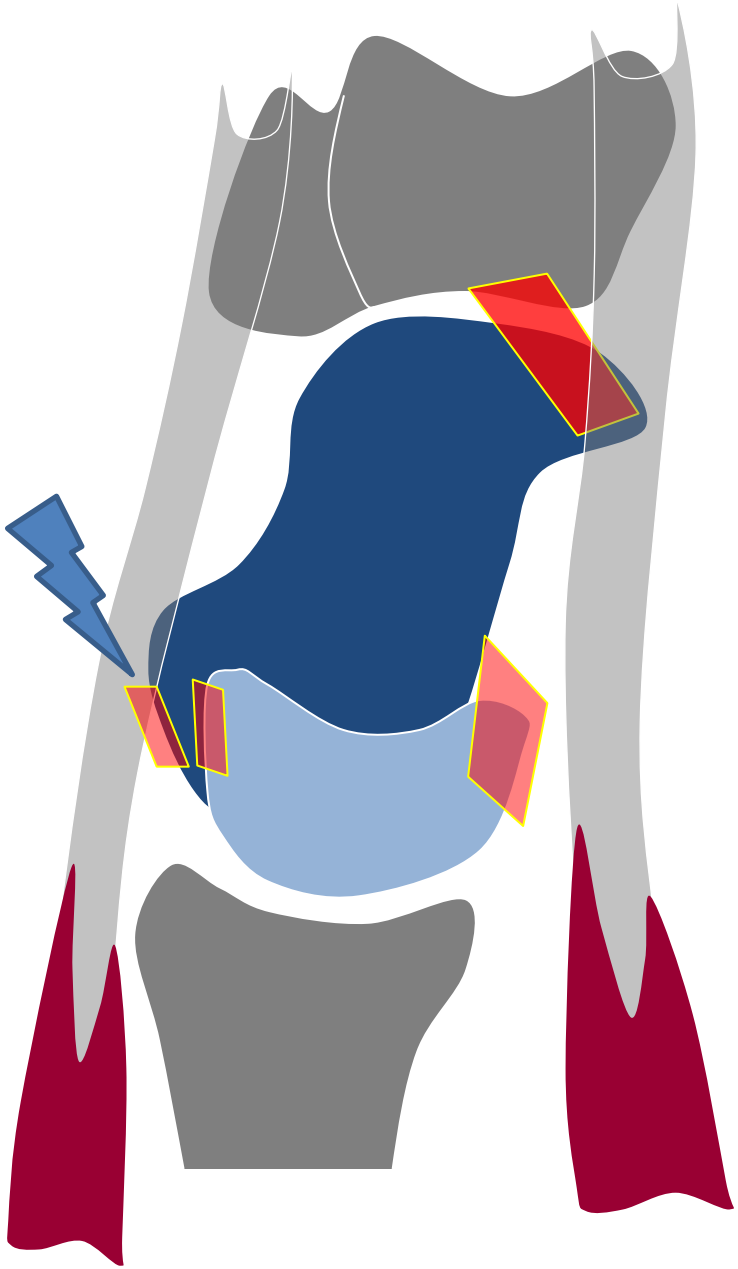


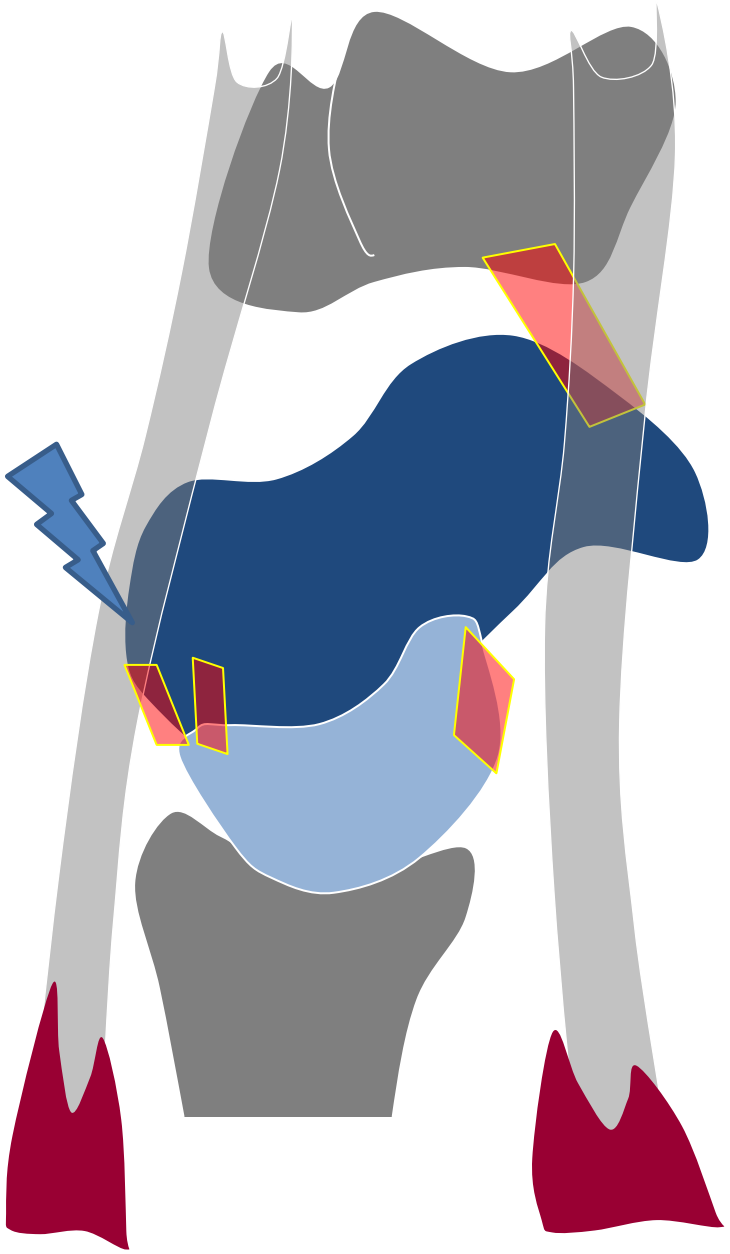
Force balance

- **Stage I- pre-dynamic**
- Partial tear of SL
- Normal et rest and normal under load
- identified only with MRI



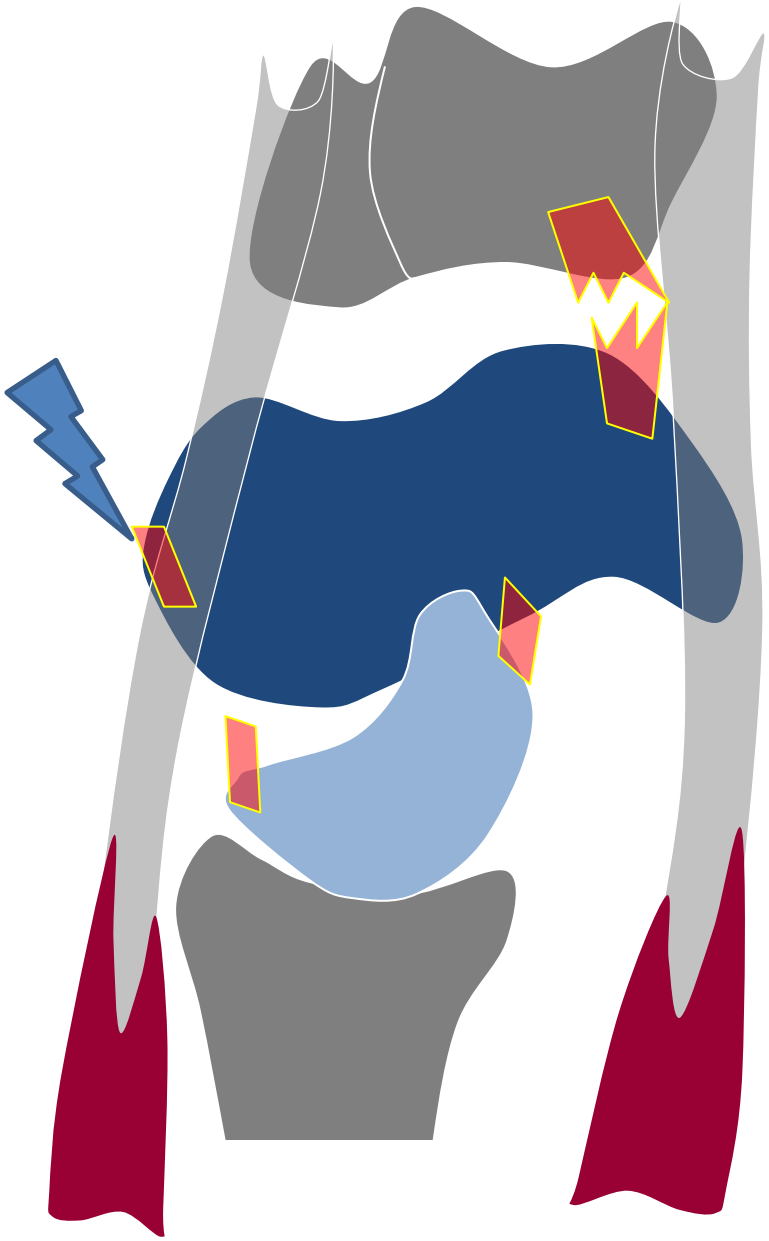
Force balance

- **Stage II-dynamic**
- complete tear of SL
- Normal et rest and ustable under load



Force balance

- **Stage II-dynamic**
- complete tear of SL
- Normal et rest and ustable under load



Force balance

- **Stage III-static**
- complete tear of SL and secondary stabilizers
- Instability et rest
- DISI pattern

Force balance

- **Stage IV - osteoarthritic**
- complete tear of SL and secondary stabilizers
- Instability et rest
- DISI pattern and SLAC

Summary

- **The wrist is a very mobile, load bearing articulation that incorporates a complex arrangement of pulleys.**
- **From a functional point of view, the midcarpal joint is more useful than the radiocarpal joint**
- **Aside from their role as static constraints, wrist ligaments are sensory structures providing proprioception information to the central nervous system.**
- **Muscles are the ultimate wrist stabilizers, their efficacy depending on a proper intra-carpal pronosupination balance.**
- **SL dissociation is an example of this balance disturbing leading to instability and arthritic changes**


Thank you for your attention