# Articulations mécaniques inspirées du coude de mammifères quadrupèdes

Santiago Arroyave-Tobon, Kalenia Marquez-Florez, Jean-Marc Linares
Aix Marseille Univ, CNRS, ISM, Marseille, France

# ISM laboratory

# ISM UMR 7287

## Interdisciplinary laboratory

- PSNM: Plasticity of Muscular and Nervous Systems
- AdapJuste: Adaptations and Adjustments
- DCI: Behavioral Dynamics and Immersion
- ICS: Interactions between Cognitive and Sensorimotor Behaviors
- CMC: Context, Motivation and Behaviors
- P3M: Motor Performance and Multiscale Modelling
- GIBOC: Interdisciplinary Group in Osteoarticular Biomechanics
- BIOROB: Biorobotic
- **CBI: Bio Inspired Design**

# CBI Research team (2021-22)

## ISM UMR 7287

## Bio inspired research team

**3 PhD**

**1 PhD**

**1 PhD**
**1 Post Doc**

**1 PhD**

**1 Post Doc**

1 Full Professor
1 Emeritus Professor
3 Associates professors
1 Indus/Univ Professor
1 Assit. Engineer

**1 Engineer**

**Doctoral grant**
ED SMH

## TechnoValo

PLATEFORME TECHNOLOGIQUE AIX-MARSEILLE

# Research activities (2021-22)

Prof. Jean-Marc Linares
Prof. Jean-Michel Sprauel (Emeritus)

## Bio-inspired research team

### Bio-inspired part structure

Dr Julien Chaves-Jacob

PhD
THALES
Bio-inspired 2D parts
(2020-22)

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### Bio-inspired design

Dr Santiago Arroyave-Tobon

PhD
AIRBUS HELICOPTERS
Joint digital twin
(2020-23)

ANR JCJC
BioDesign
(2020-24)

DASSAULT SYSTEMES
La Fondation

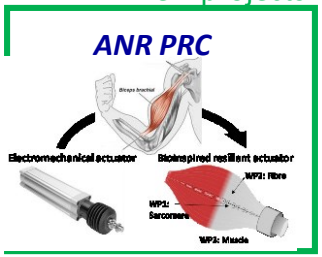
### Bio-actuators and dampers

Dr Loic Tadrist

PhD
AIRBUS HELICOPTERS
*Electromechanical actuators lifetime*
*(2021-24)*

new projects

ANR PRC




### Chaire AMU/AH


2016-20
Prof. Emmanuel Mermoz

PhD
AIRBUS HELICOPTERS
Load in biological joints
(2017-20)

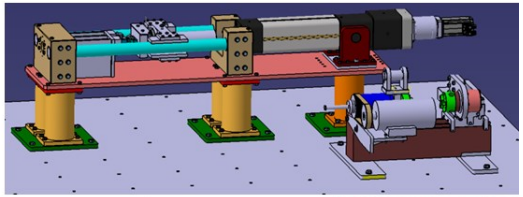
PhD
AIRBUS HELICOPTERS
Bio-inspired joints
(2018-20)

INSTITUT DES SCIENCES DU MOUVEMENT ETIENNE JULES MAREY

# Team research equipment

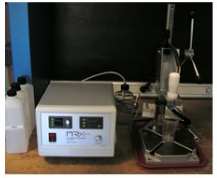
**Additive manufacturing**

**Digital image correlation and tracking**



**Residual stress (MRX Compagny)**

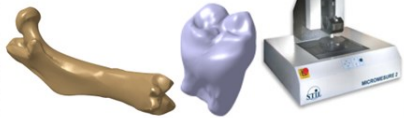

**Testing**



**Polishing operations**

**Material integrity**

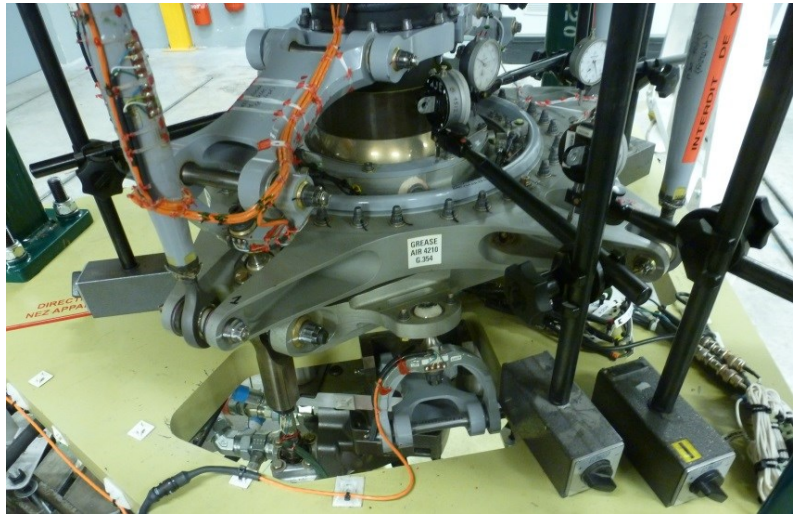
**Geometry**

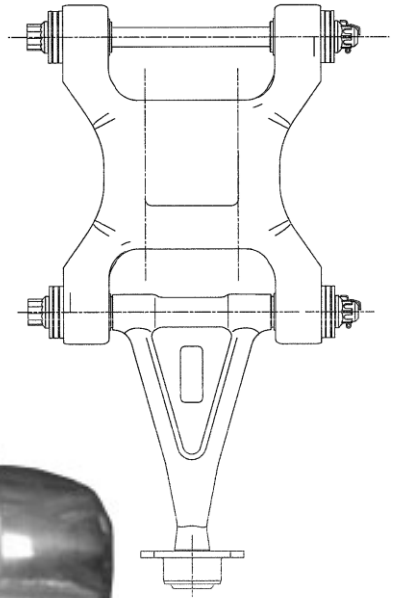


# Articulations mécaniques inspirées du coude de mammifères quadrupèdes

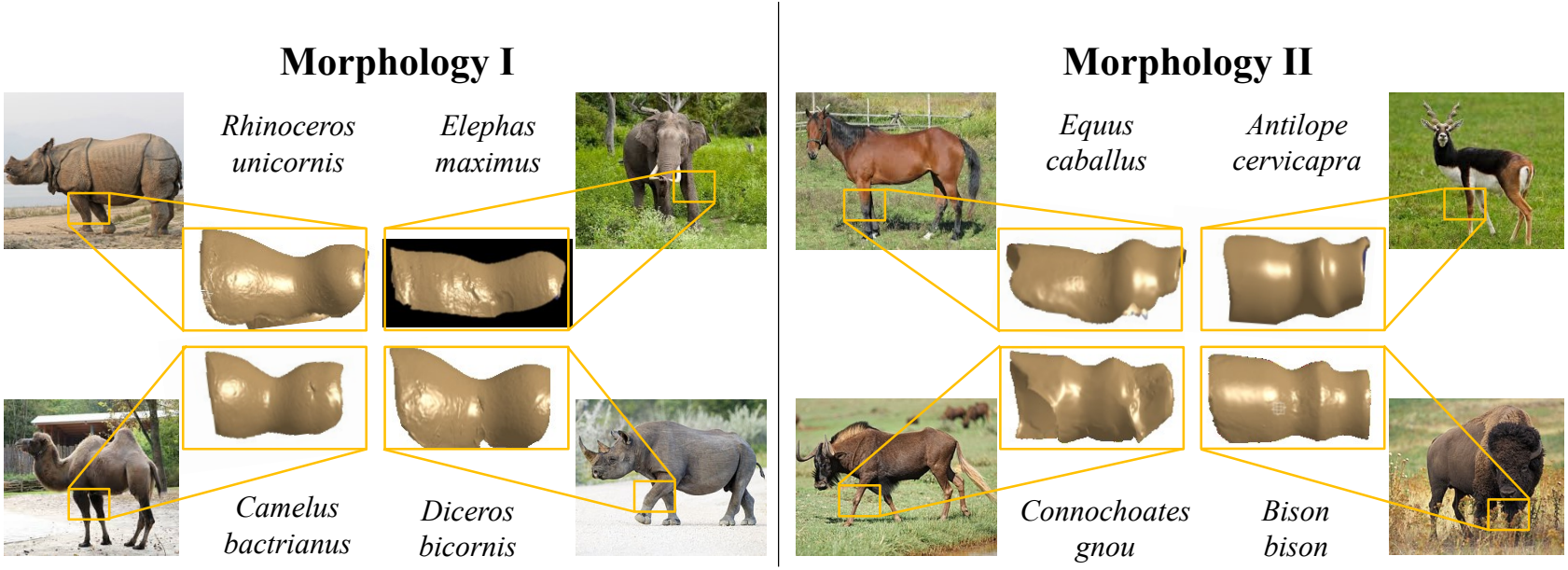
# Industrial issues

- Mechanical linkages are heavily tested, but in-service experience is showing sometimes the apparition of wear that requires significant maintenance burdens for the customer.





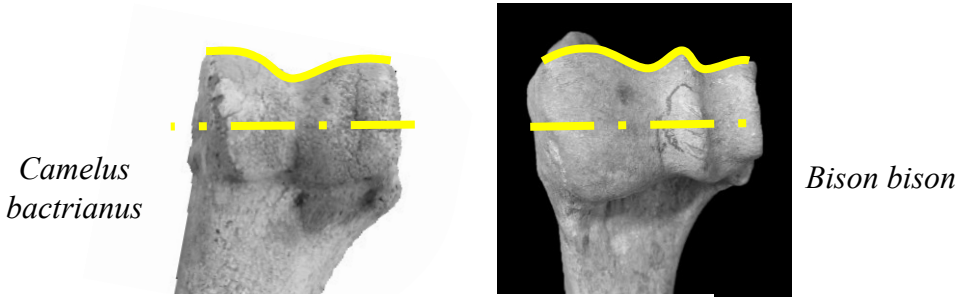
# Endoskeletons developed different morphologies for revolute joints




Collections from the Natural History Museum of Paris

Which are the **functional advantages** of these morphologies?

# Schedule: bio-inspiration at two levels




**Level 1:** understand the relation **structure-function**

Sanz-Idirin, A., Arroyave-Tobon, S., Linares, J.-M., Arrazola, P.J.
*Bioinspiration & Biomimetics,* 2021, 16(4), 046025

Earlier work

**Level 2:** mimic morphological **mechano-adaptation**

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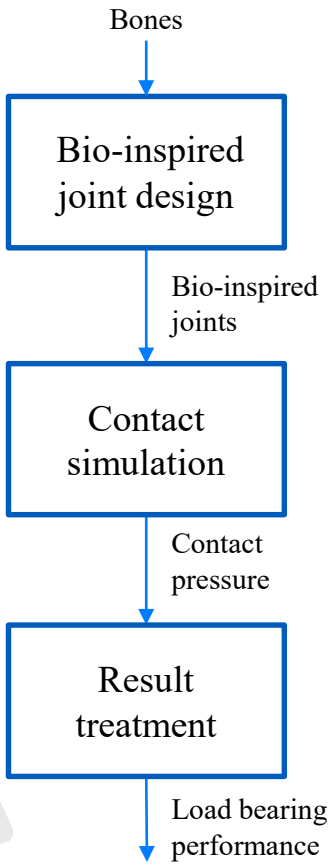
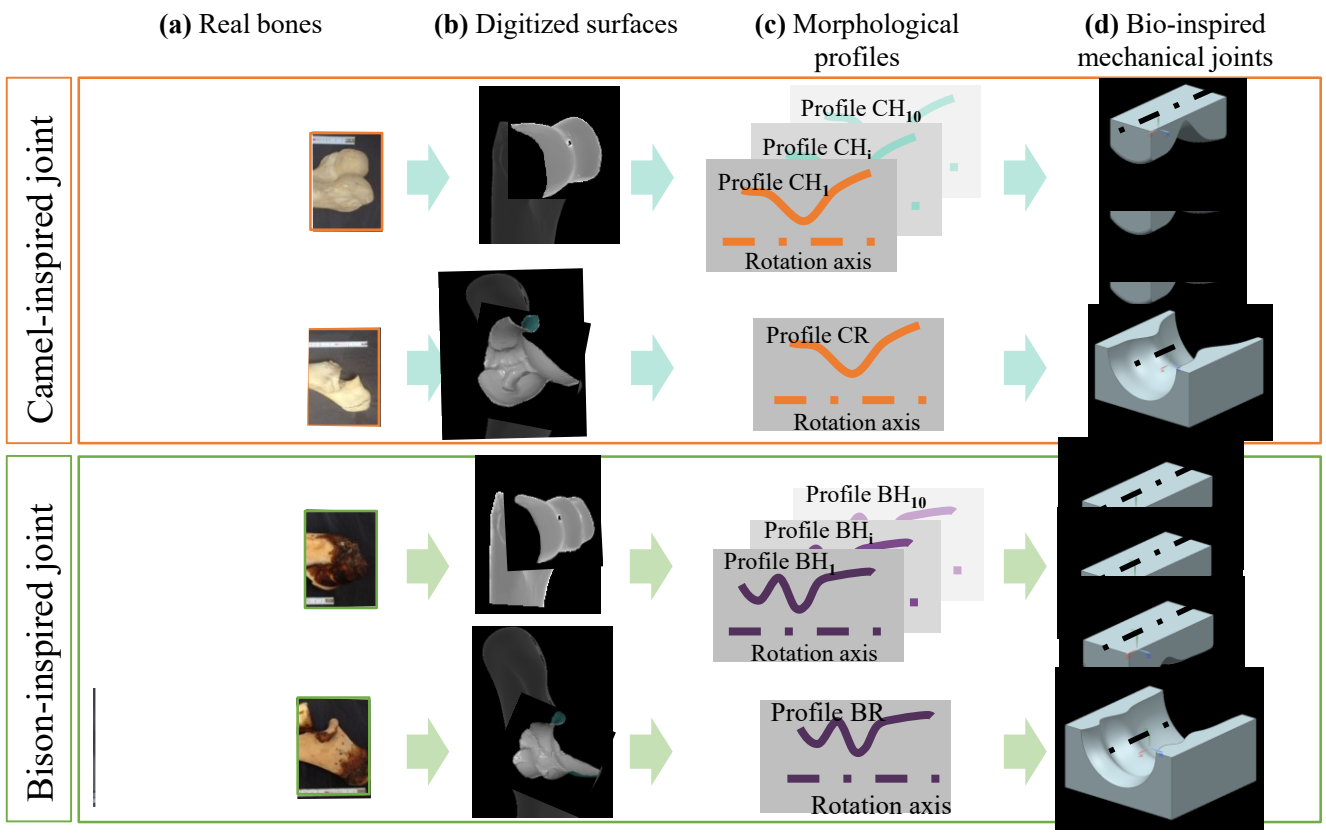
Ongoing work

# Level 1: understand the relation structure-function

# From camel and bison bones to mechanical joints



# Contact simulations of bio-inspired joints

Bones

Bio-inspired joint design

Bio-inspired joints

**Contact simulation**

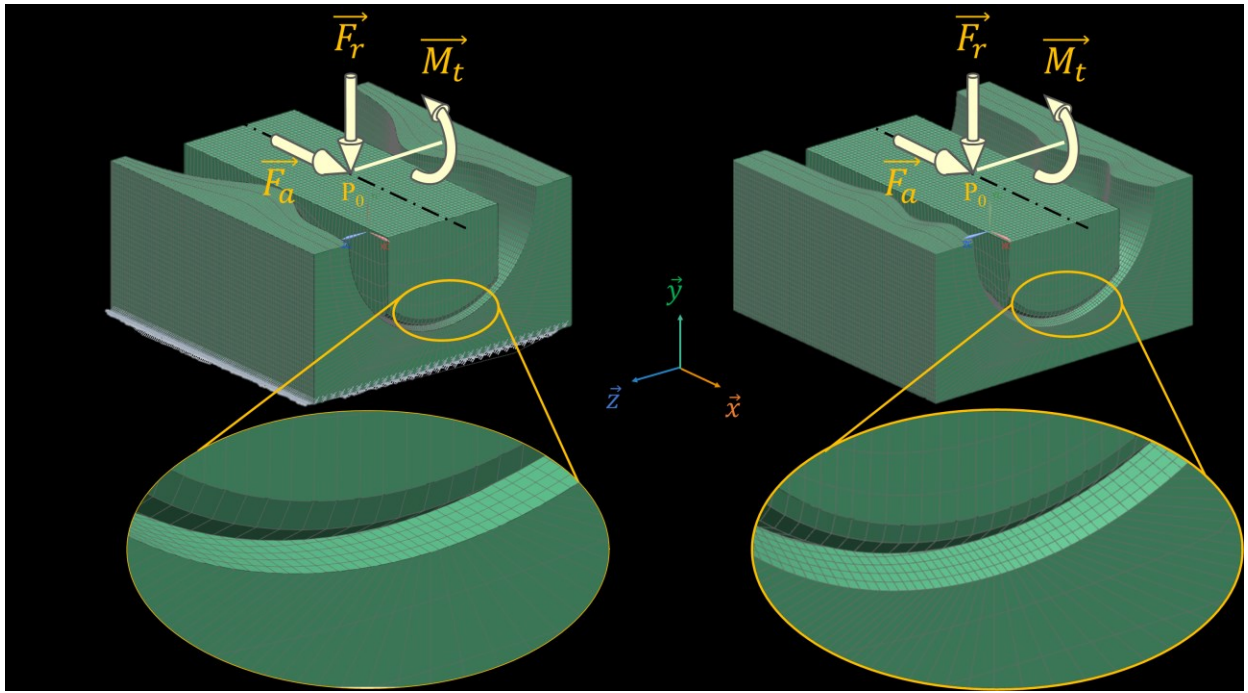
Contact pressure

Result treatment

Load bearing performance

Camel-inspired joint

Bison-inspired joint



# Bearing performance to combined loads

Bones

Bio-inspired joint design

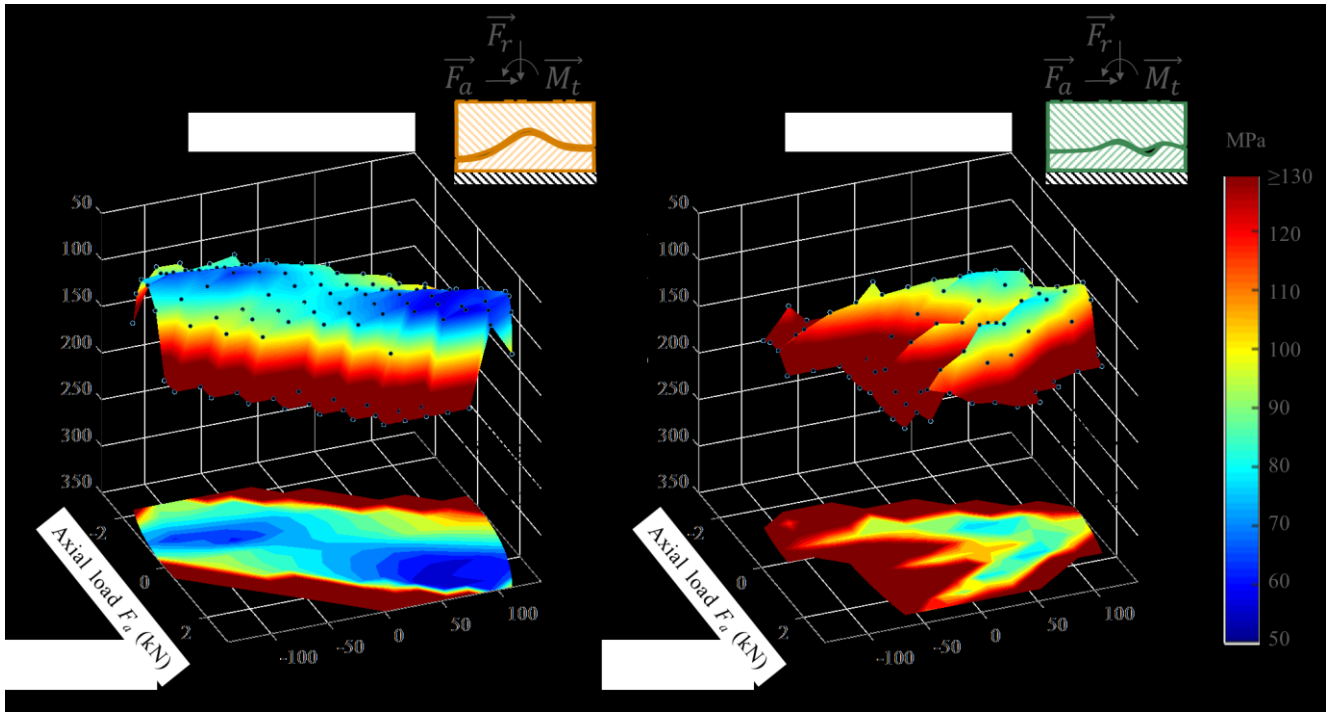
Bio-inspired joints

Contact simulation

Contact pressure

**Result treatment**

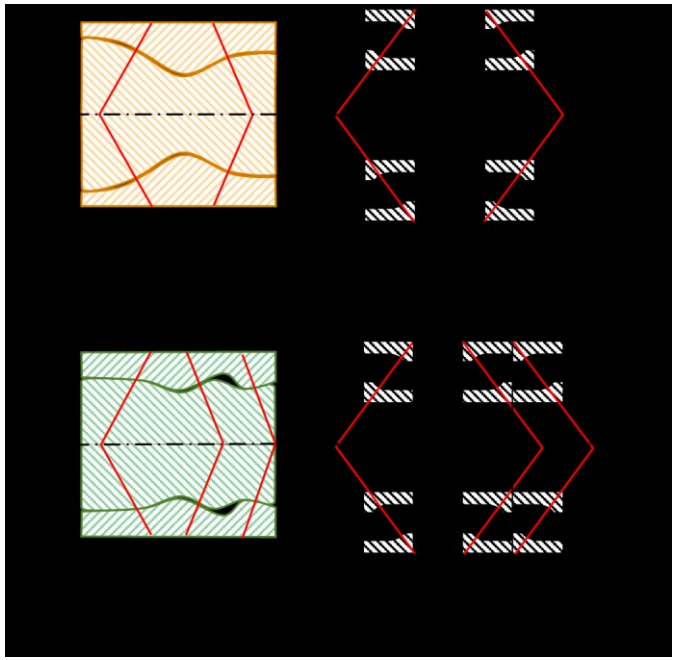
Load bearing performance

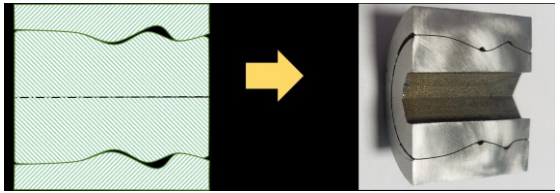



720 numerical simulations were conducted using Samcef solver

# Conclusions about level 1

- Asymmetrical response regarding load transmission.
- Preferential loading conditions not far from the physiological loading.
- Camel-inspired joint:
  - more suitable for supporting combined loads.
  - similar to back-to-back (DB) bearing arrangement.
- Bison-inspired joint:
  - more specialized for bearing turnover moments.
  - similar to a back-to-back and tandem (TBT) arrangement.





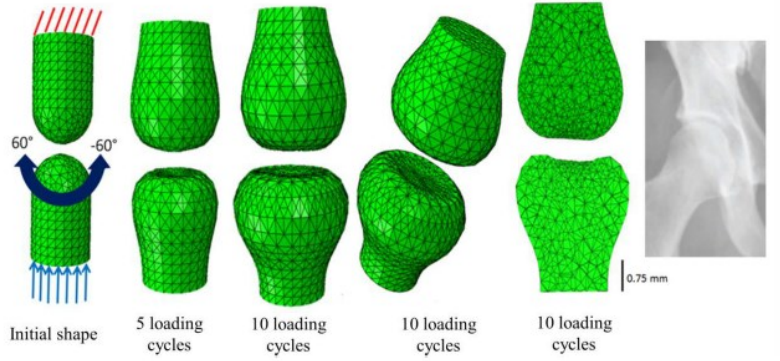
# Level 2: mimic morphological mechano-adaptation

# State of the art: joint morphogenesis

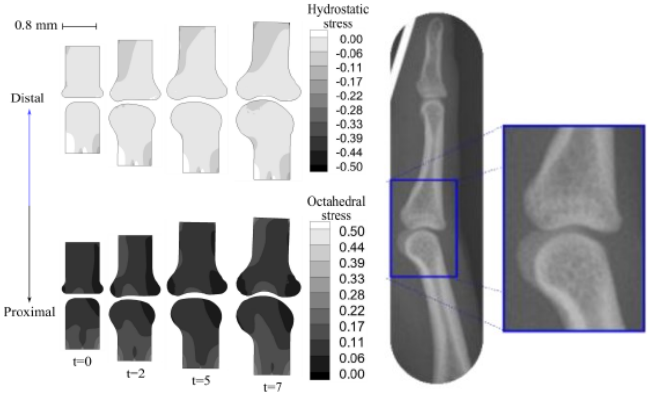
**Joint morphogenesis:** biochemical + mechanical factors

biochemical: molecular distribution (Turing, 1952), mechano-transduction

mechanical: mechano-adaptation (Wolff, 1892; Guilak,1994), cartilage differentiation (Carter and Wong, 2003)



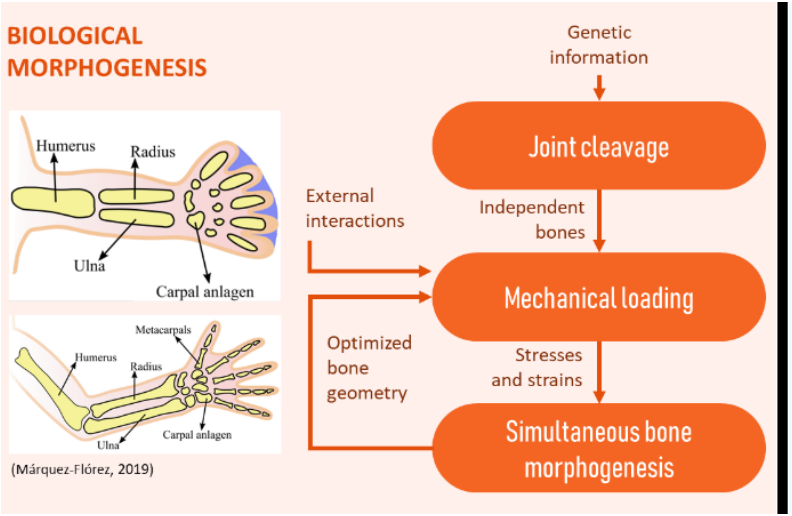

Giorgi M., Mechanobiological predictions of fetal joint morphogenesis, 2015, Phd Thesis, Imperial College.




Márquez-Flórez K., Mechanobiological computational model for the development and formation of synovial joints, 2019, Phd Thesis, Universidad Nacional de Colombia.

# Mimicking morphological mechano-adaptation

**Research hypothesis:** bone morphogenesis process can be mimicked in engineering to automate the design of mechanisms.

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# Thanks for your attention

# Preferential loading conditions

Bones

Bio-inspired joint design

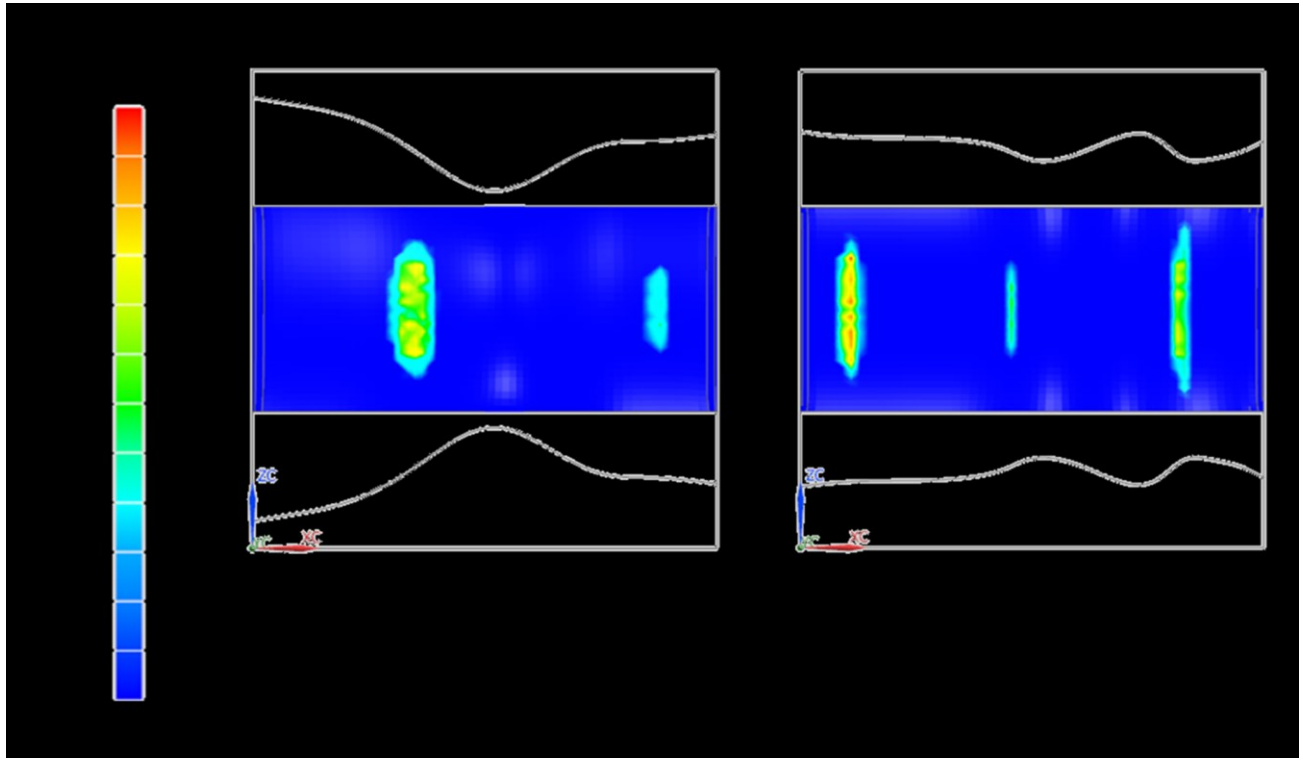
Bio-inspired joints

Contact simulation

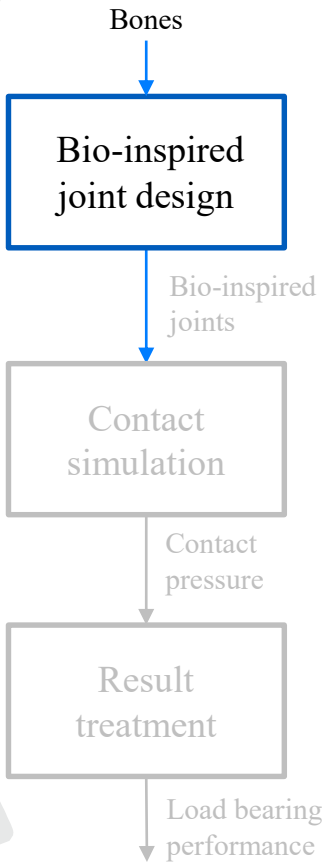
Contact pressure

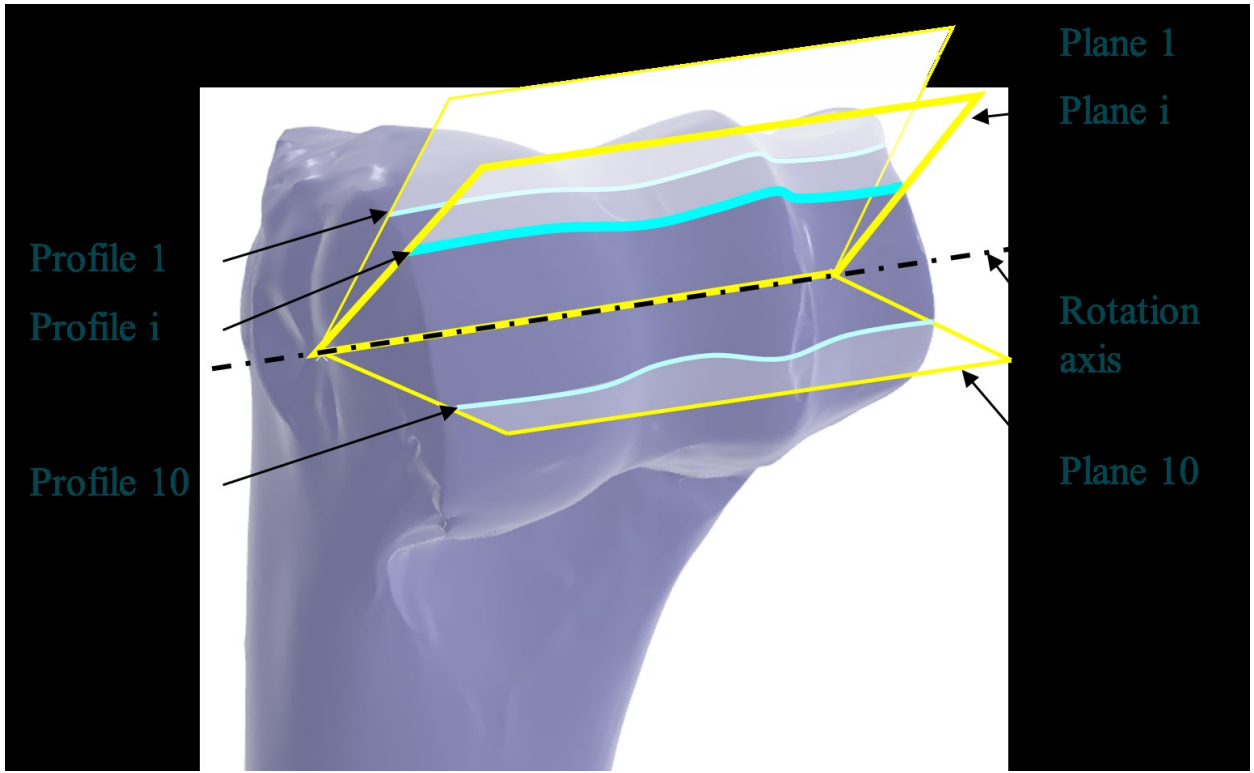
Result treatment

Load bearing performance



# Extraction of morphological profiles



# Axial load bearing performance

Bones

Bio-inspired joint design

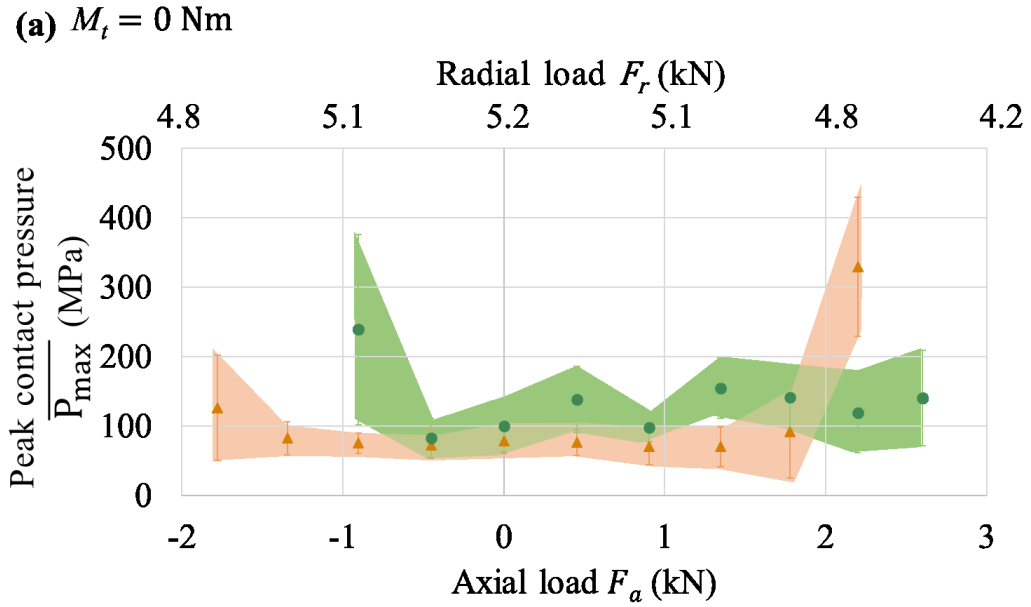
Bio-inspired joints

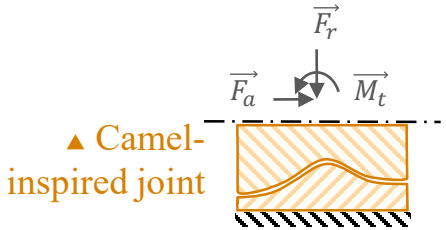
Contact simulation

Contact pressure

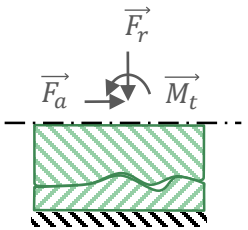
Result treatment

Load bearing performance




▲ Camel-inspired joint




● Bison-inspired joint

# Tournover moment bearing performance