BONE-FIBROCARTILAGE CROSSTALK & OSTEOCYTE LACUNO-CANALICULAR NETWORK AT THE TENDON-BONE INSERTION

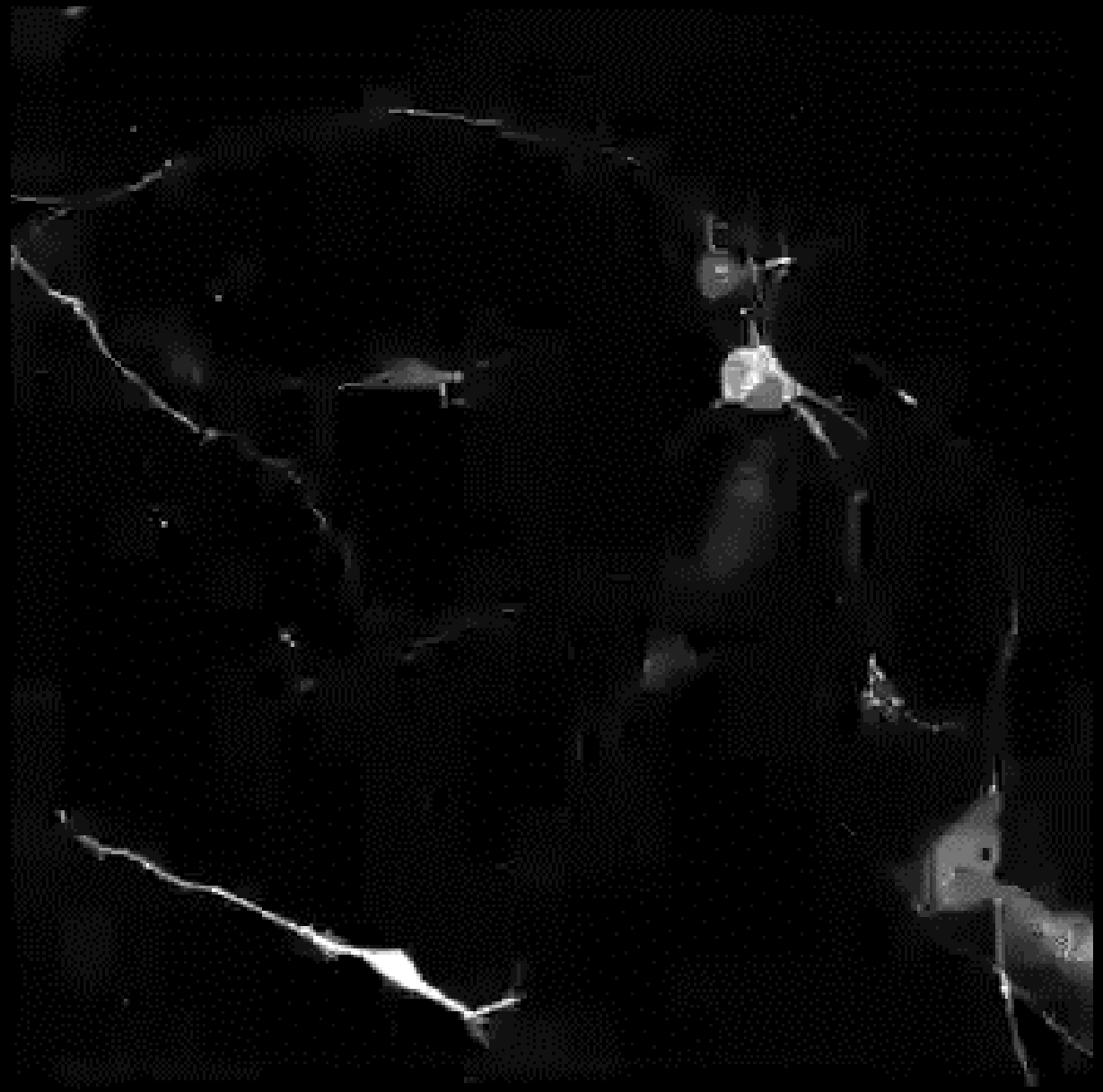
A Tits [1], S Blouin [3], M Rummler [4], JF Kaux [1], P Drion [1], GH van Lenthe [2], R Weinkamer [4], MA Hartmann [3], D Ruffoni [1]

[1] University of Liège, Liège, Belgium ; [2] KU Leuven, Leuven, Belgium
[3] Ludwig Boltzmann Institute of Osteology, Vienna, Austria
[4] Max Planck Institute of Colloids and Interfaces, Potsdam, Germany

ESB2023
28th Congress of the European Society of Biomechanics
9-12 July 2023, Maastricht, The Netherlands

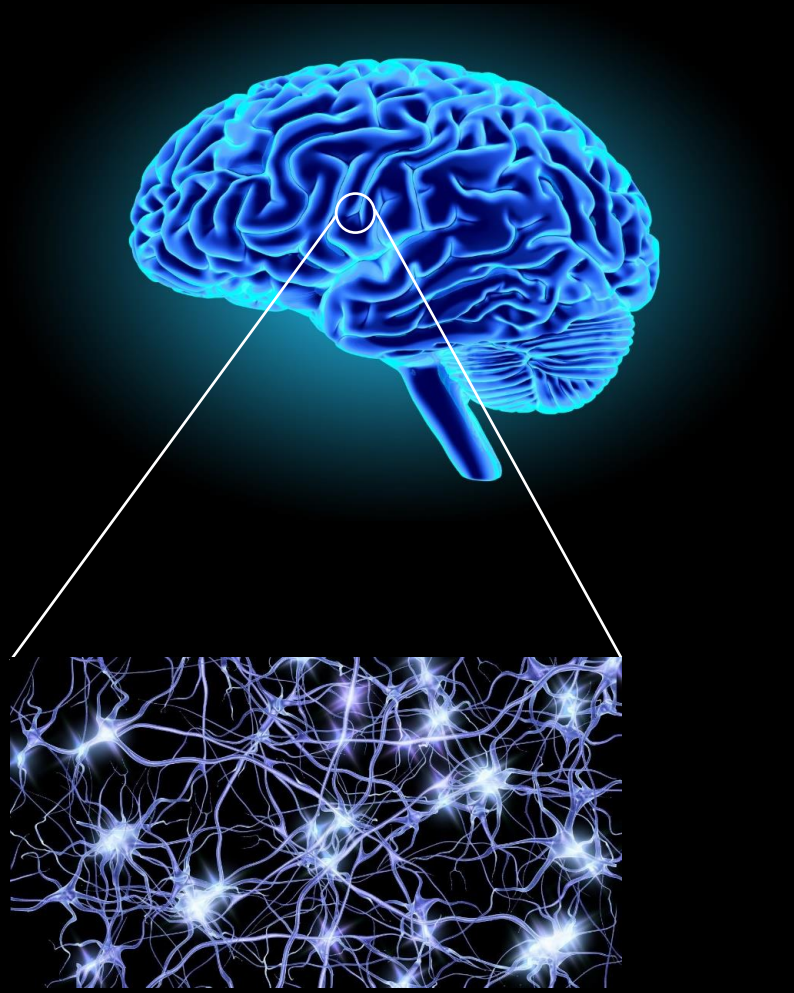
10/07/2023
atits@uliege.be
www.biomat.uliege.be

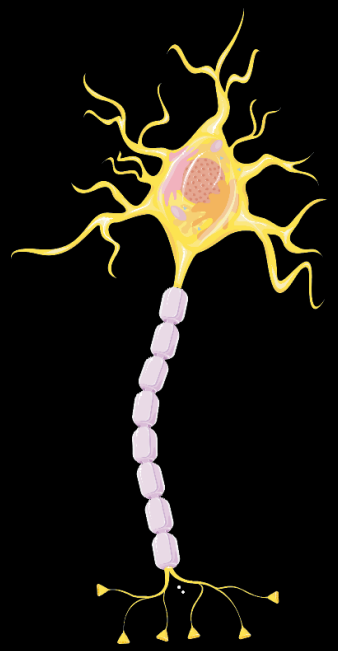
MBBM



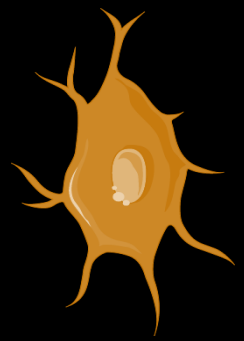
https://www.youtube.com/shorts/A9zLKmt2nHo

Bone as a local & self-organized brain

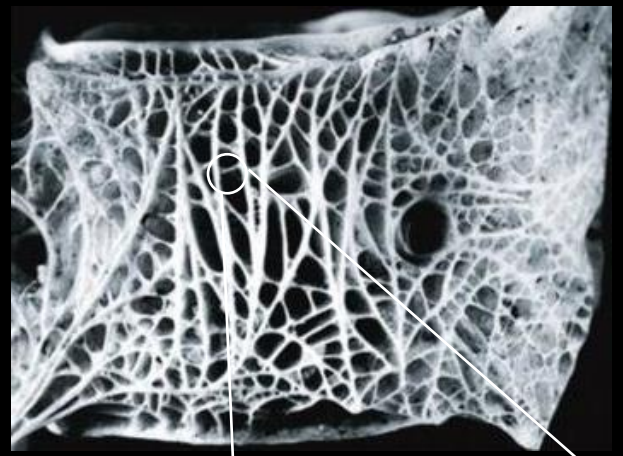


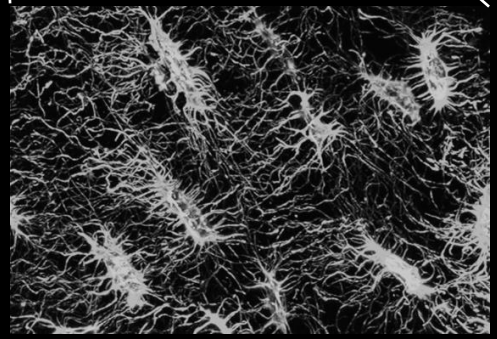


Neuron



Osteocyte





https://www.genengnews.com/news/neurons-affected-by-epilepsy-identified/

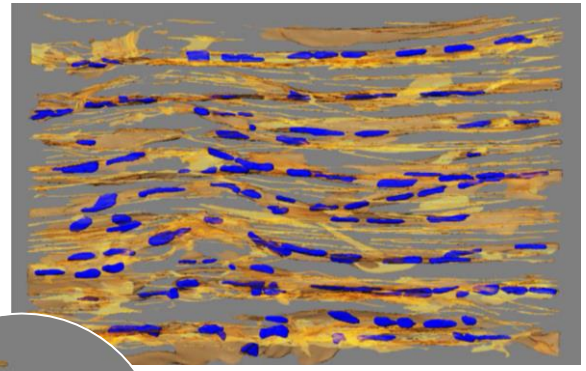
Kamel-ElSayed et al., Bone, 2015

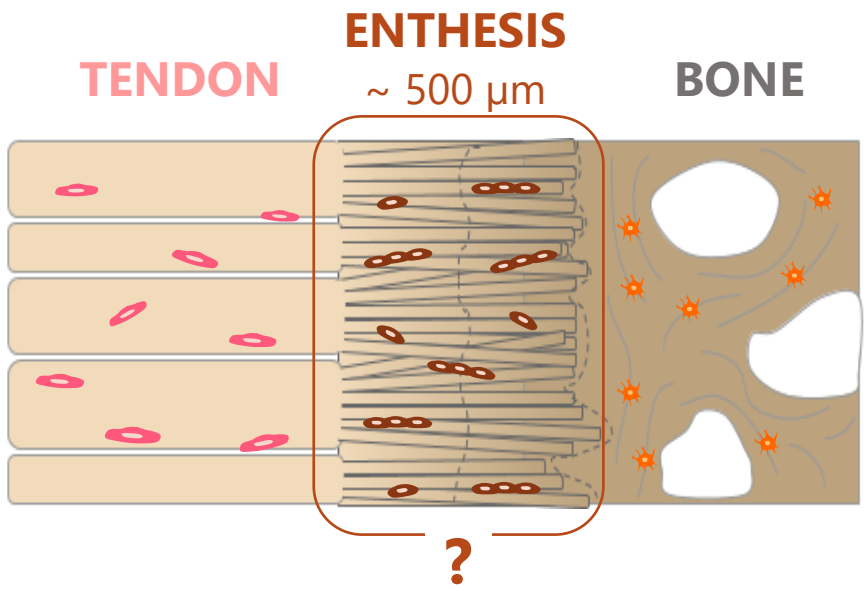
The specific case of **entheses**

Tendons and **bones** contain cells having *communication abilities* thanks to underlying networks of sub-micrometers channels

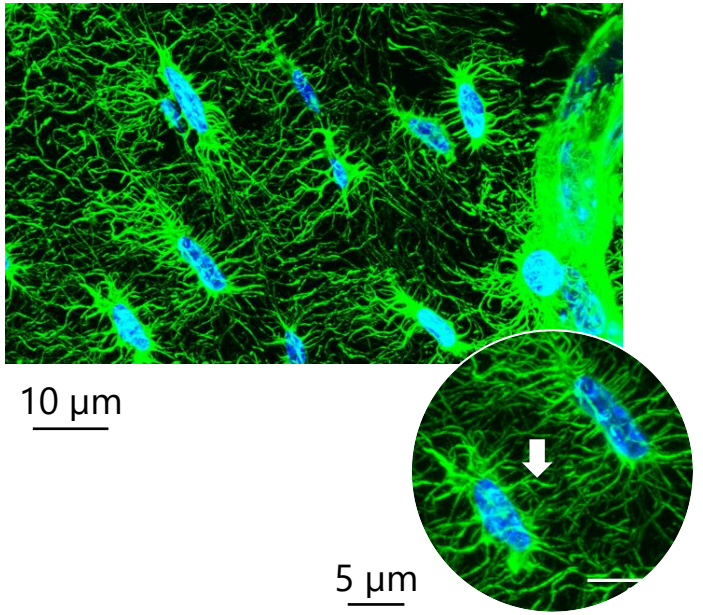
Ankle joint

Tenocytes form a 3D network and are connected via *nanotubes*



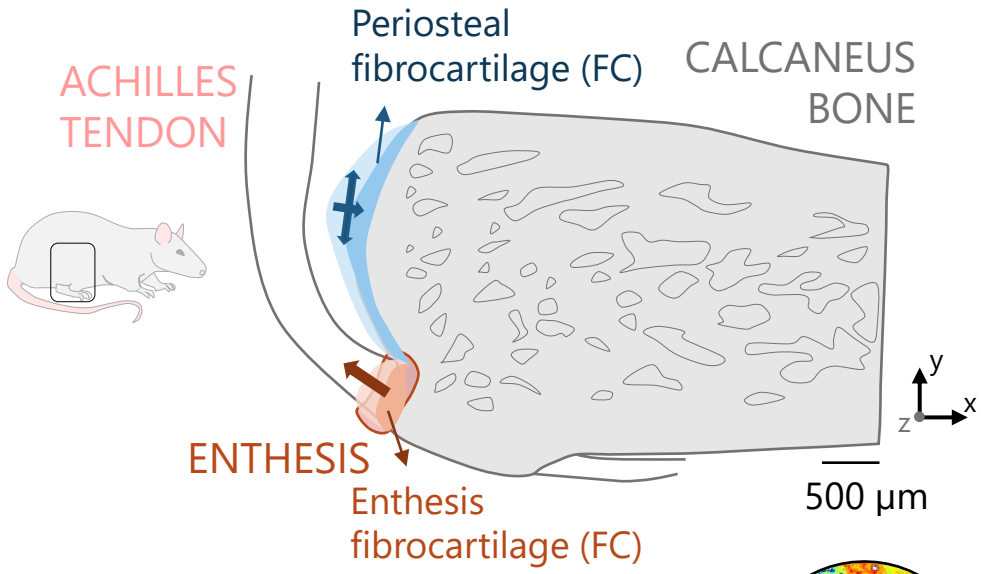


Osteocytes are connected through a complex osteocyte *lacuno-canalicular network*



Egerbacher et al., J. Anatomy, 2020 ; Kamel-ElSayed et al., Bone, 2015
https://www.istockphoto.com

Previous studies and current research aims



PREVIOUS STUDIES

Several **mineralized tissue types** exhibiting specific microstructural and microporous aspects: very strong **anisotropy** at the **insertion**

Tits et al., Sci Rep 2021

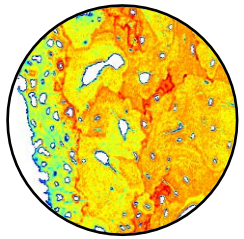
Fibrocartilage is a **versatile** tissue

- High **strength** at the insertion
- **Gradual** compliance at the periosteal surface

Tits et al., Acta Bio 2023

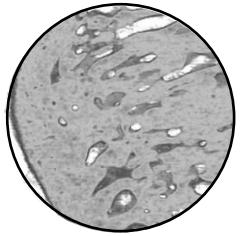
CURRENT RESEARCH

Explore mineralized fibrocartilage-bone **crosstalk** and subchondral bone **functional nanoporosity**



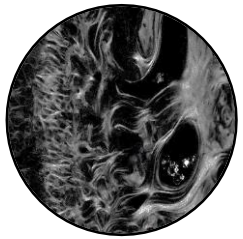
qBEI (1)
Pixel size: 0.88 µm

(1) Quantitative backscattered electron imaging



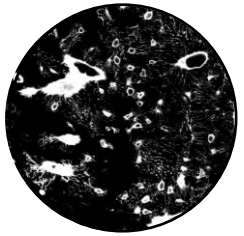
micro-CT (3)
Pixel size: 2 µm

(3) Micro-computed tomography



SHG (2)
Pixel size: 0.38 µm

(2) Second harmonic generation



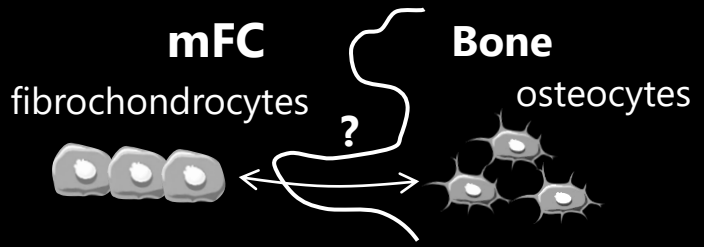
CLSM (4)
Pixel size: 0.24 µm

(4) Confocal laser scanning microscope

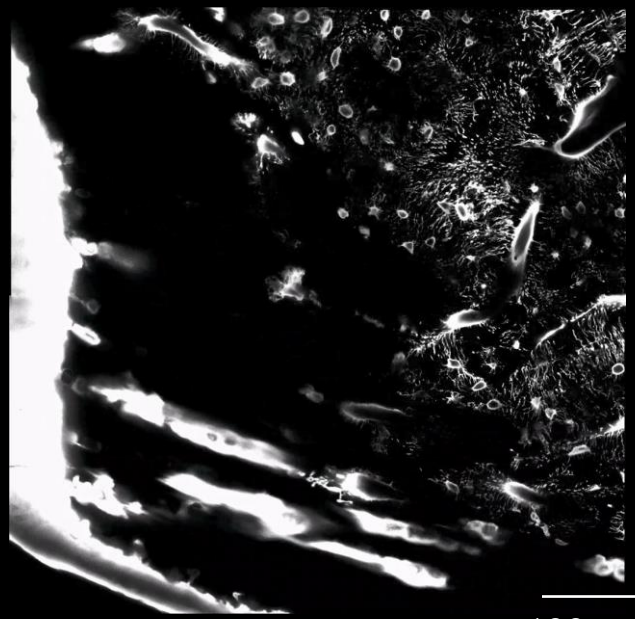
Staining agent (rhodamine)

Bone-fibrocartilage **crosstalk**

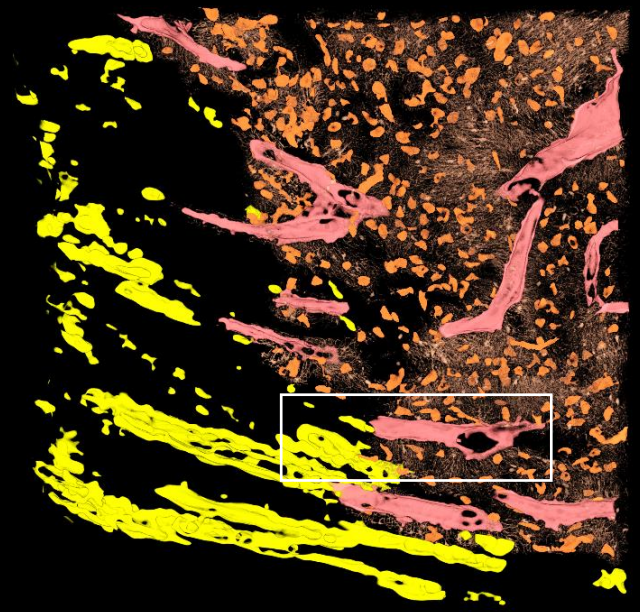
Segmentation of **osteocyte lacuno-canalicular network, fibrochondrocytes and channels** close to the interface

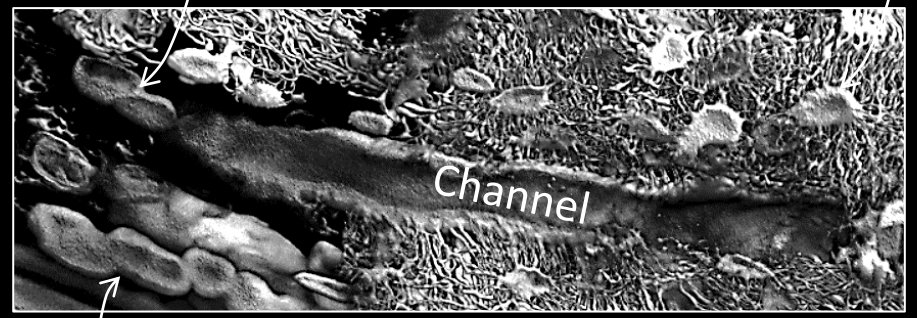


I. ENTHESIS REGION



CLSM

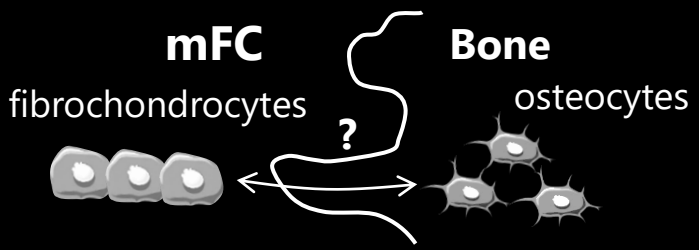




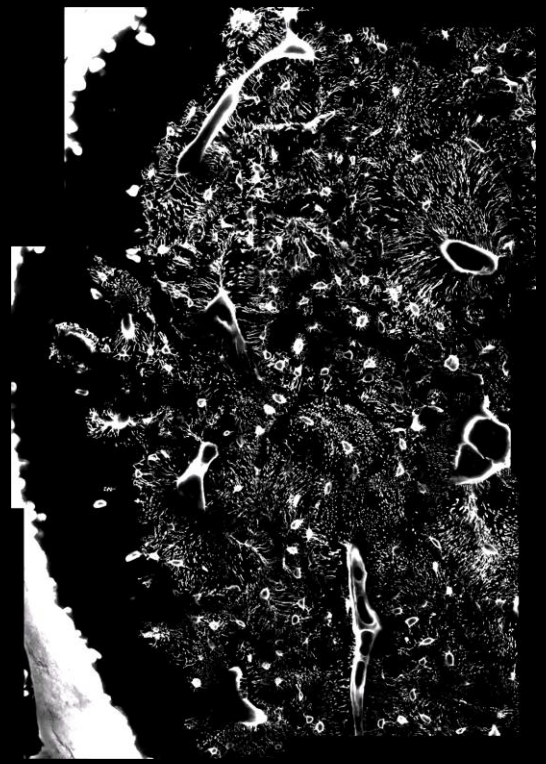
- Entire rows of **stained fibrochondrocytes**
- Densely **decorated** perforating **channels**

Bone-fibrocartilage **crosstalk**

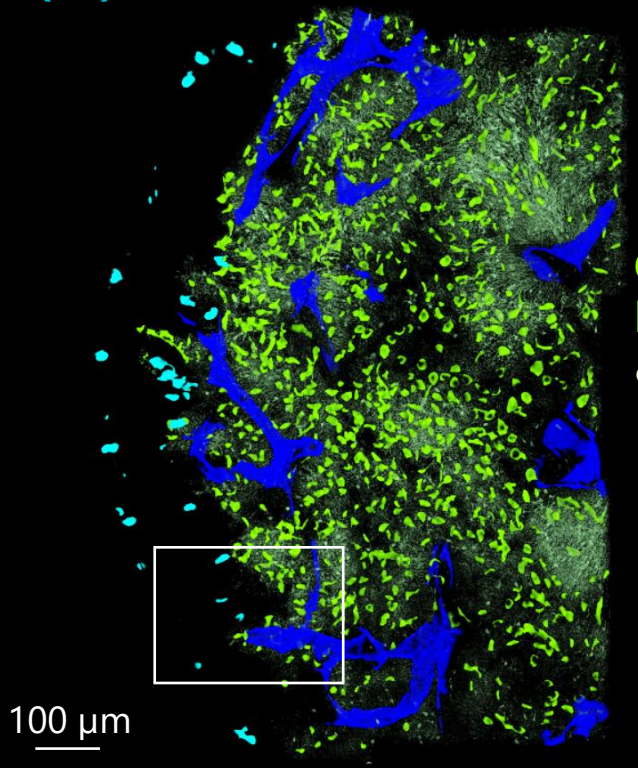
Segmentation of **osteocyte lacuno-canalicular network, fibrochondrocytes and channels** close to the interface



CLSM

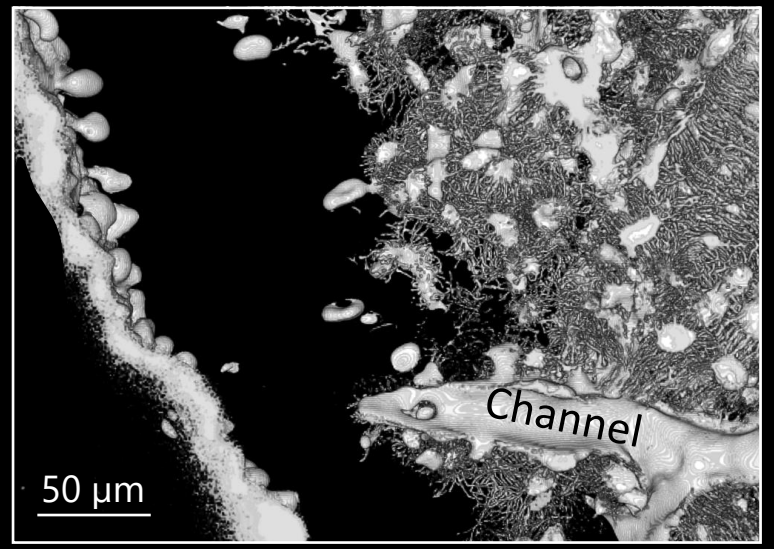


Fibrochondrocyte (FC) lacunae Subchondral **bone** channel network



Osteocyte lacunae & canaliculi

uFC mFC bone



Much less stained fibrochondrocytes and interactions

Bone-fibrocartilage **crosstalk**

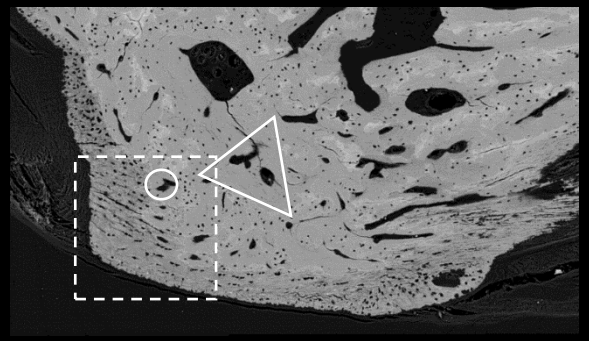
Analysis of **osteocytes - fibrochondrocytes** interactions close to the interface between bone and fibrocartilage

Bone-fibrocartilage **crosstalk**

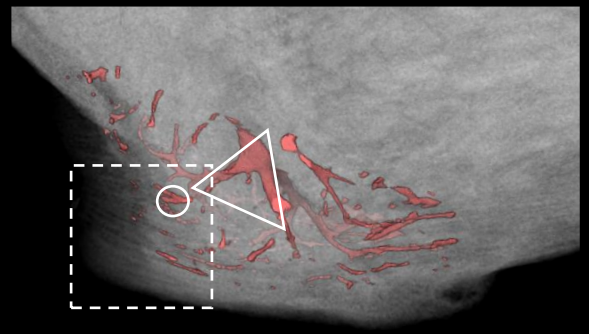
Correlation of the imaging techniques to understand crosstalk and highlight the origin of the **perforating channels**

ENTHESIS REGION

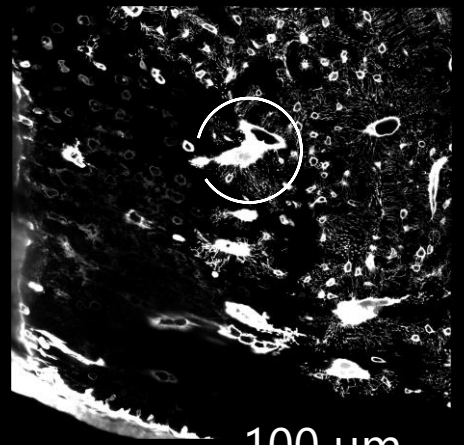
qBEI



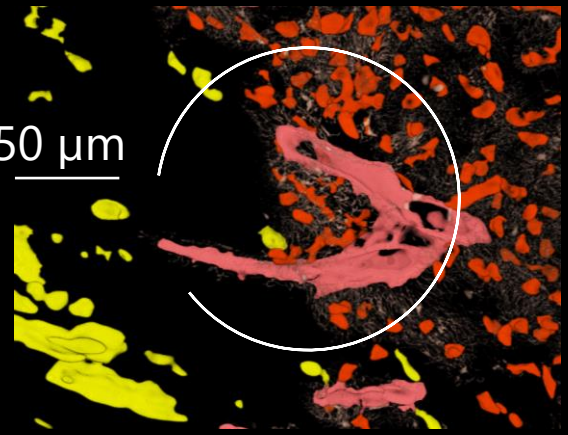
micro-CT



CLSM



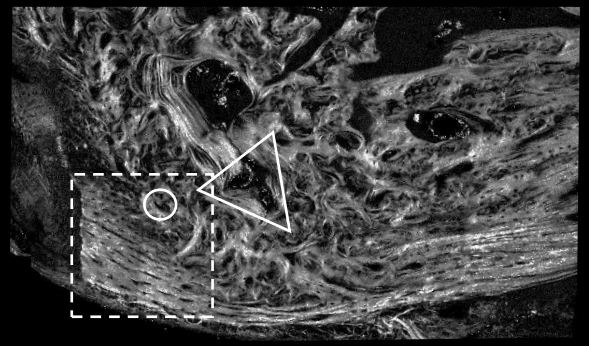
100 µm



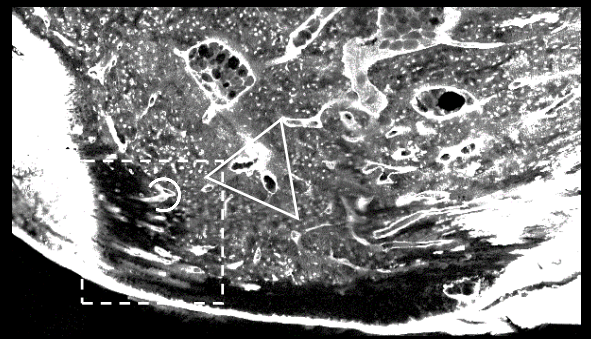
50 µm

250 µm

SHG



CLSM



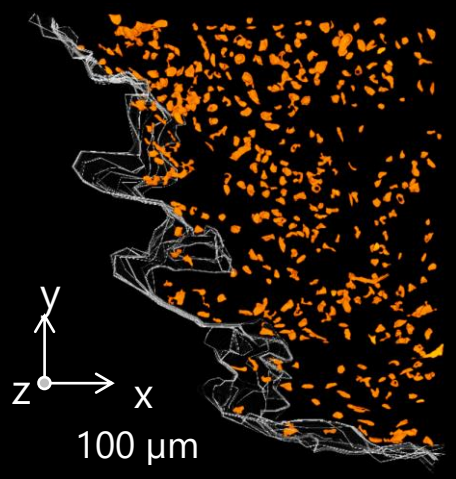
Rhodamine path to fibrochondrocyte rows: at the insertion, **mainly** through perforating channels originating from the **trabecular <u>bone marrow space</u>** and reaching <u>fibrocartilage</u>

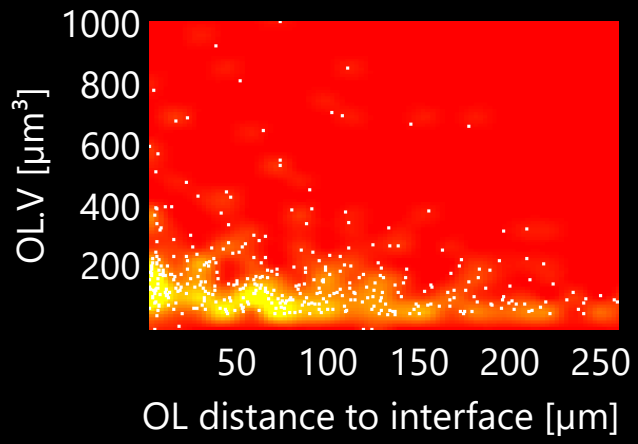
Bone **nanoporosity** close to the interface

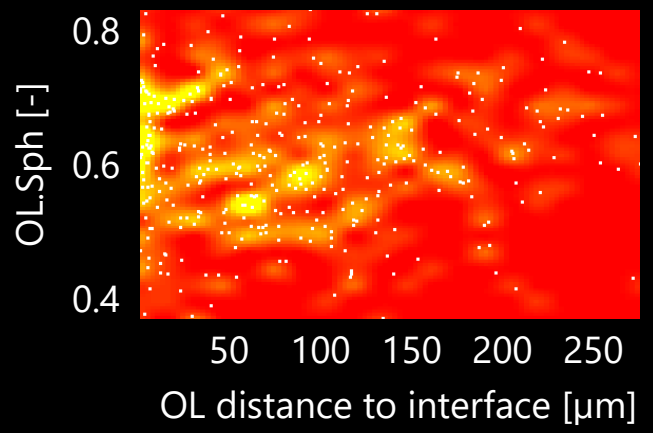
Quantification of bone **osteocyte** lacunae (OL) density and morphology at the interface with fibrocartilage

I. ENTHESIS REGION

~ 68 10^3 OL/mm^3

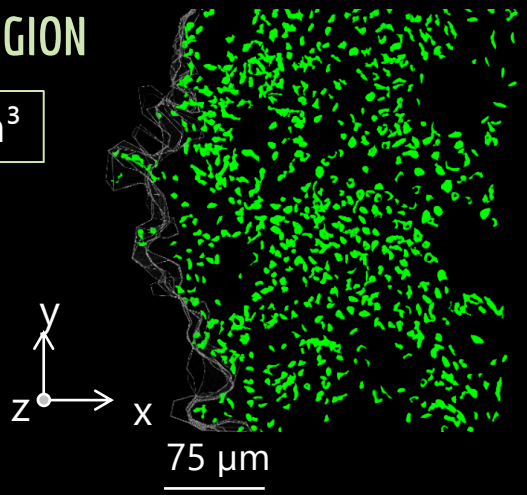




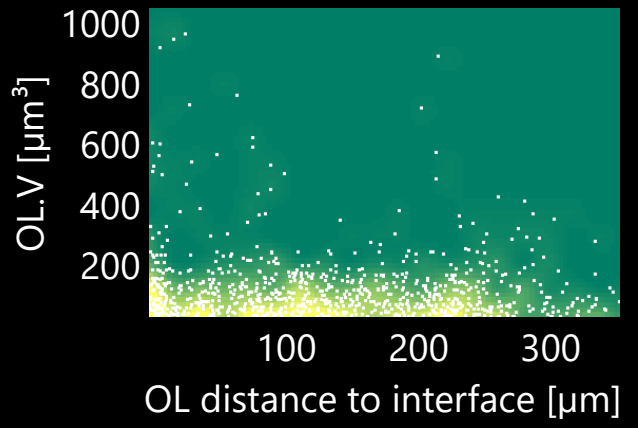


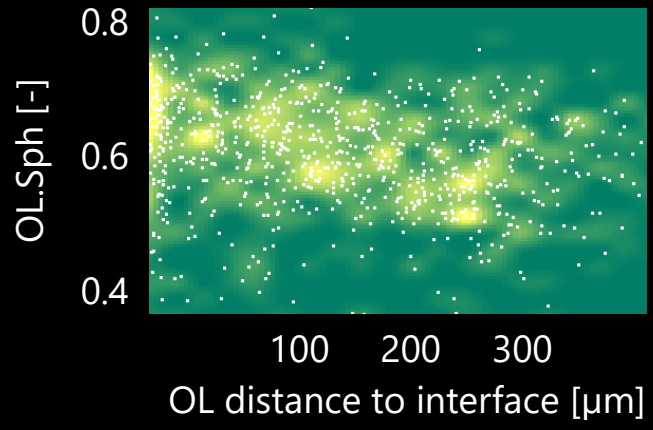
II. PERIOSTEAL REGION

~ 60 10^3 OL/mm^3



No clear trend in osteocyte morphology when reaching the interface



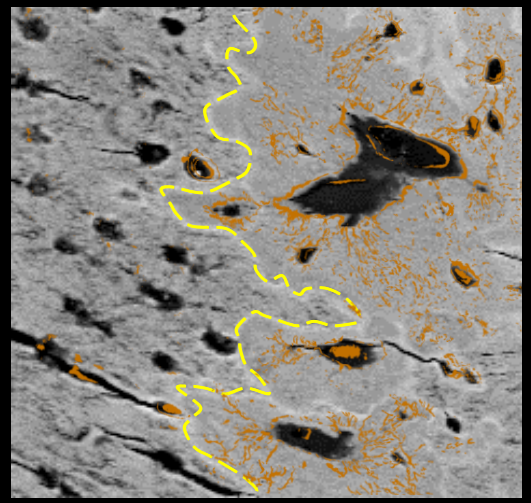


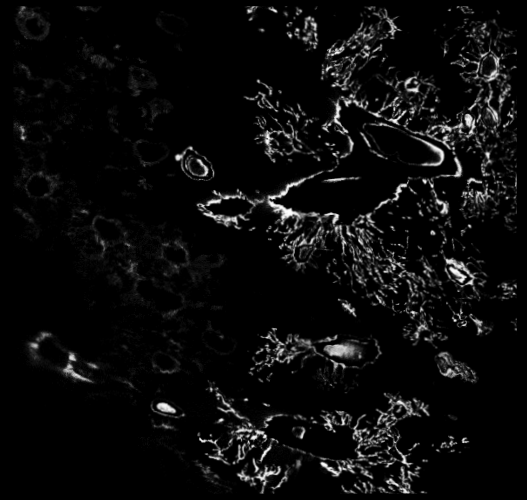
Bone **nanoporosity** close to the interface

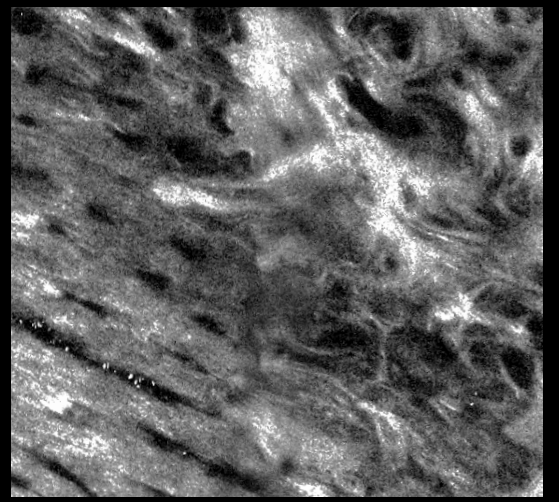
Characterization of bone **osteocyte lacuno-canalicular network** behavior close to the interface with fibrocartilage

qBEI | CLSM | SHG

I. ENTHESIS REGION

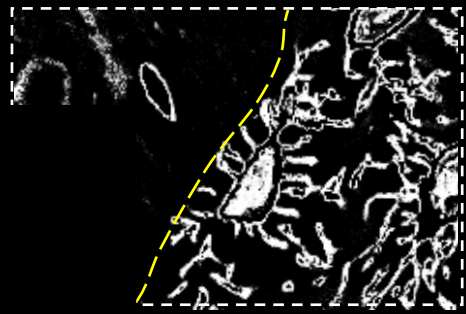






25 µm

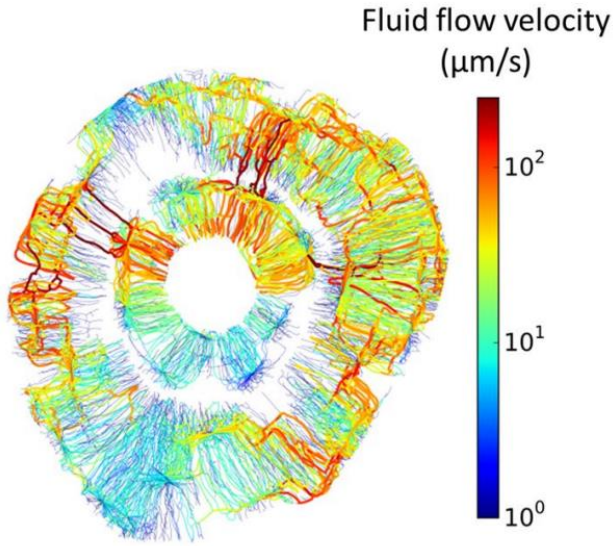
Canaliculi **stop** either at the interface or even **a few µm before**



Conclusions & perspectives

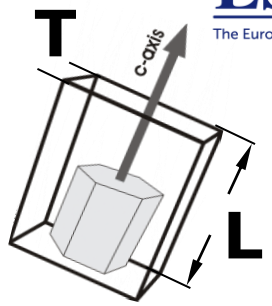
Fibrocartilage - bone communication paths

- Quantification of the permeability of the bone-FC interface, through fluid flow simulations
- New avenues to access fibrocartilage with the long-term goal of treating fibrocartilage rheumatic pathologies

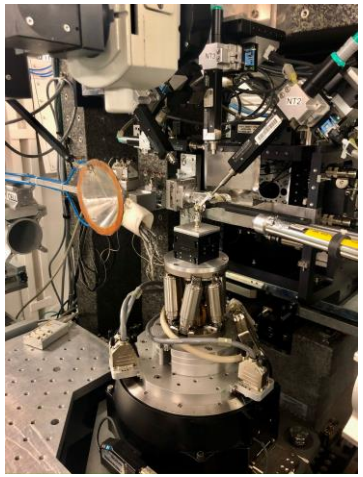


Osteocytes only weakly affected by the interface

- Quantification of mineral crystal orientation and morphology within mineralized tissues



ESRF
The European Synchrotron



Many thanks to the co-authors!

Davide
RUFFONI

Harry G
VAN LENTHE

KU LEUVEN

Pierre
DRION

Jean-François
KAUX

CHU de Liège

Stéphane
BLOUIN

Markus
HARTMANN

Maximilian
RUMMLER

Richard
WEINKAMER

Thank you for your attention!

Tits et al., Bone Reports 2021

Tits et al., Scientific Reports 2021

Tits et al., Acta Biomaterialia 2023

Alexandra Tits

@alexandra_tits