Elettra Sincrotrone Trieste

Advancing life sciences research through multiscale X-ray phase-contrast tomography

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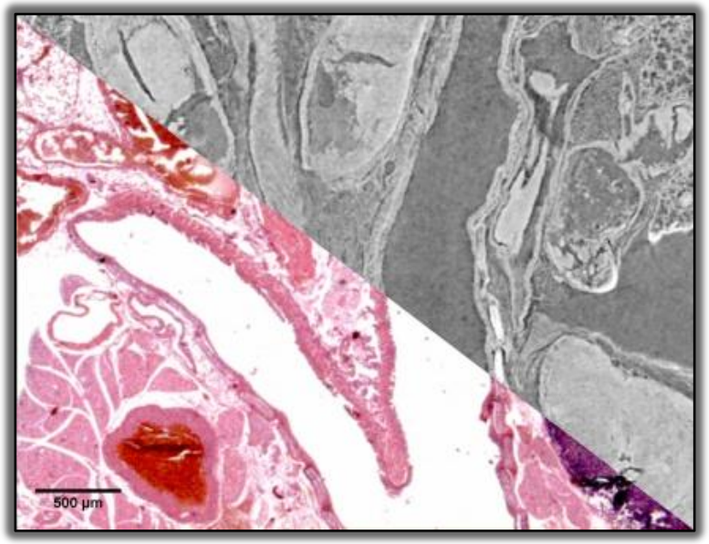
XPCT: a 3D virtual histology tool

- X-ray Phase-Contrast Tomography (XPCT) enables 3D insights of a specimen in a non-invasive way.
- Non-extensive sample preparation, no staining, no physical sample sectioning.
- Hierarchical imaging.
- Complementary to classical histology.
- Illustrative examples using propagation-based imaging.

Phase contrast image



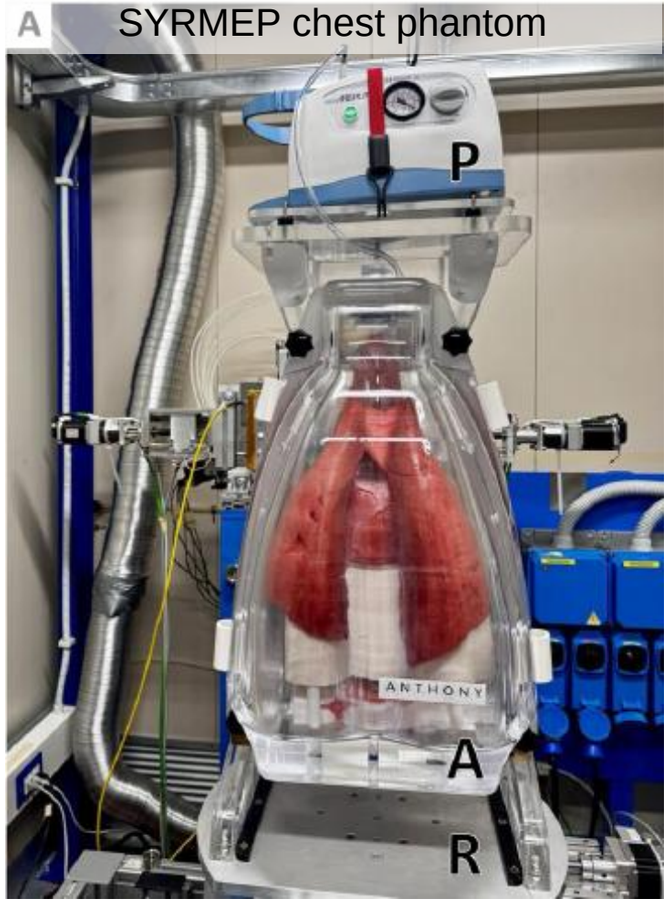
Histology

3D rendering

E. Longo et al. European Physical Journal Plus 139, 880 (2024).

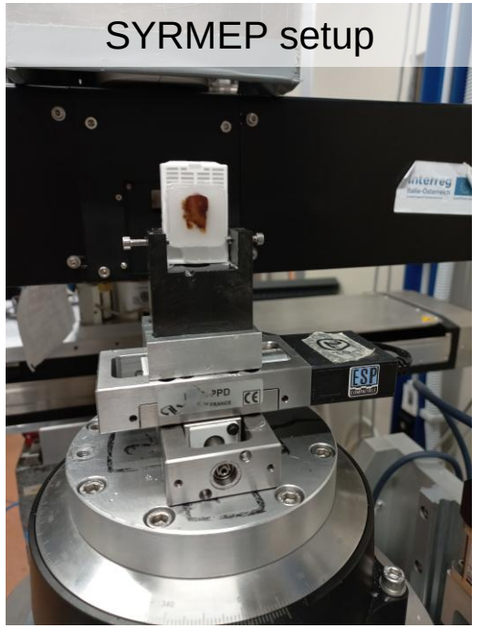
Variety of samples

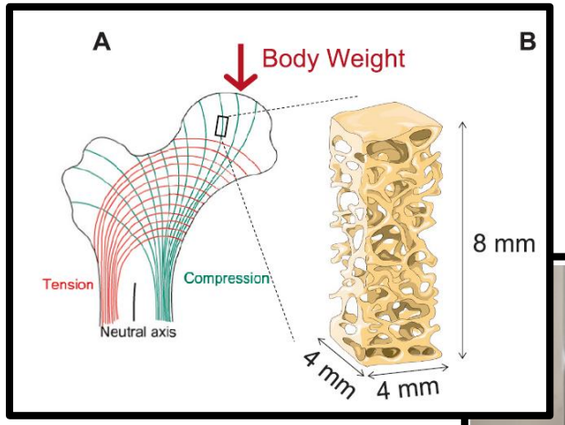
- **Human-sized samples**



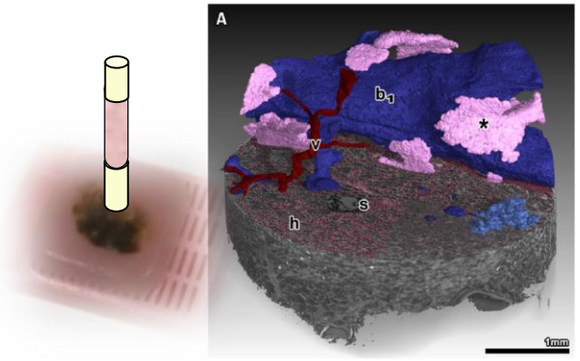
C.V. Benke et al. Respiratory Research 27, 1, 105 (2026).

- **FFPE: Formalin Fixed Paraffin Embedded tissues**





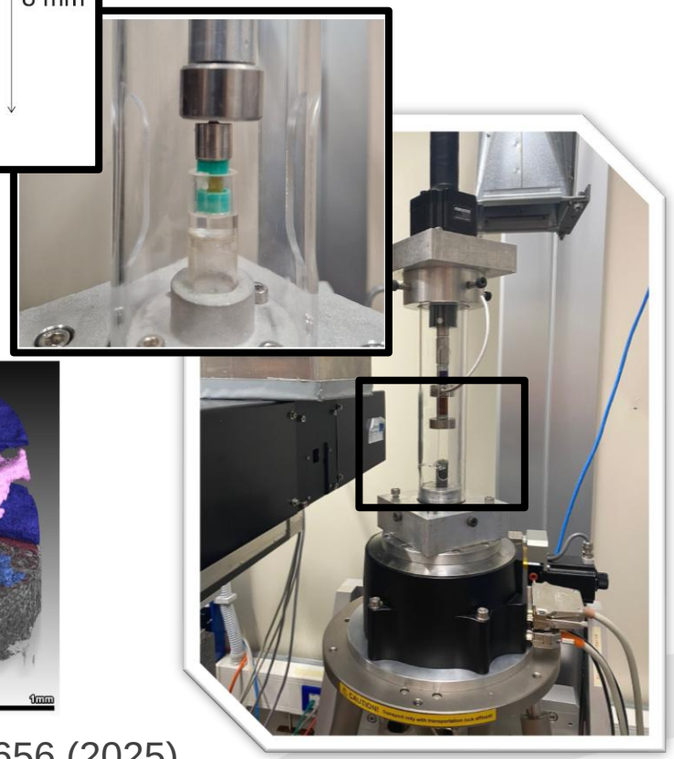
- **Biopsy punches**



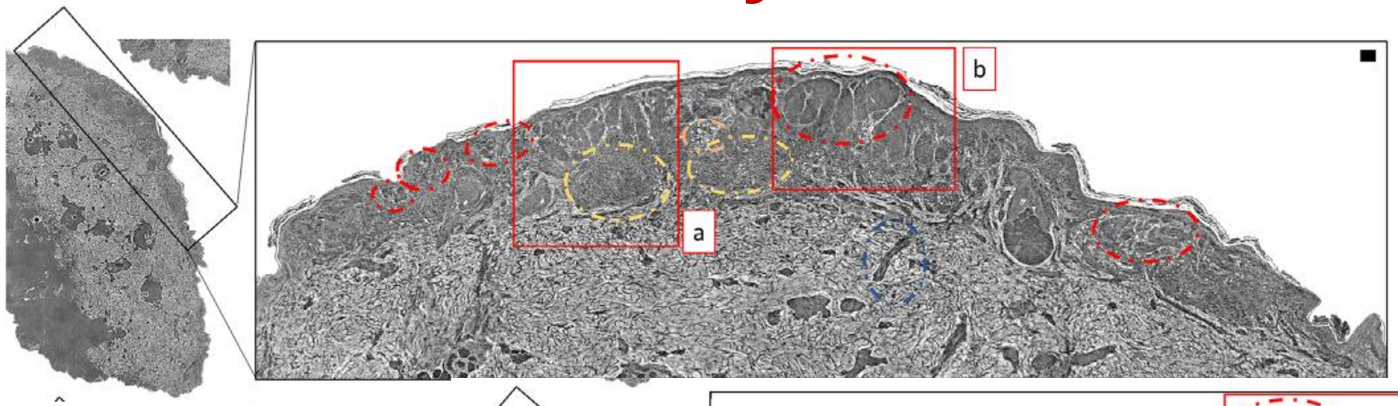
J. Reiser *et al*. *Sci. Rep.* 15, 18656 (2025).

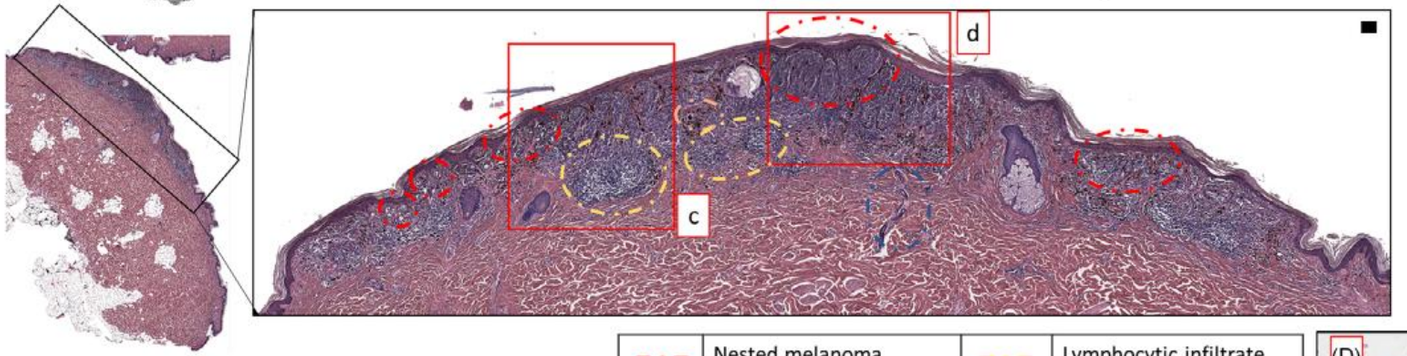
- **Bones**
- **Biomaterials**
- **In-situ device**

L. Clementini et al. Materials & Design 257, 114408 (2025).



X-ray virtual histology of skin tumors

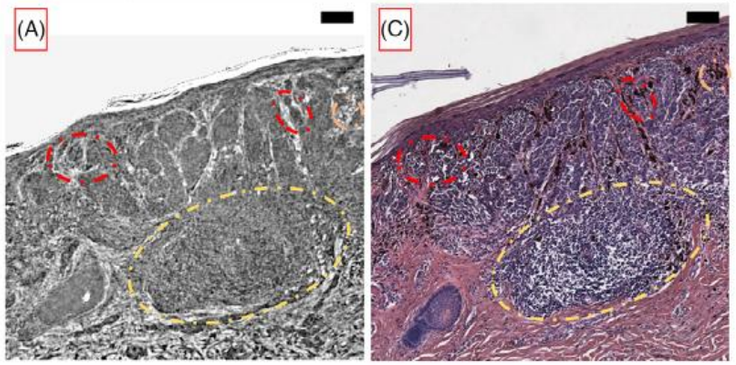


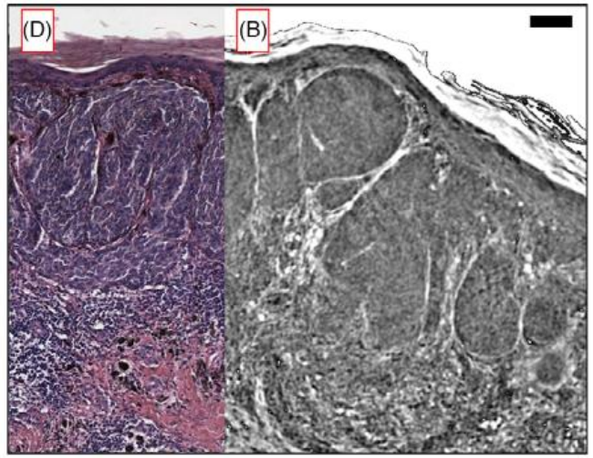


- Histopathological analysis is the gold standard in clinical practice for diagnosing **skin neoplasms**.
- X-ray virtual histology reproduces diagnostic features.

Samples included in the study:

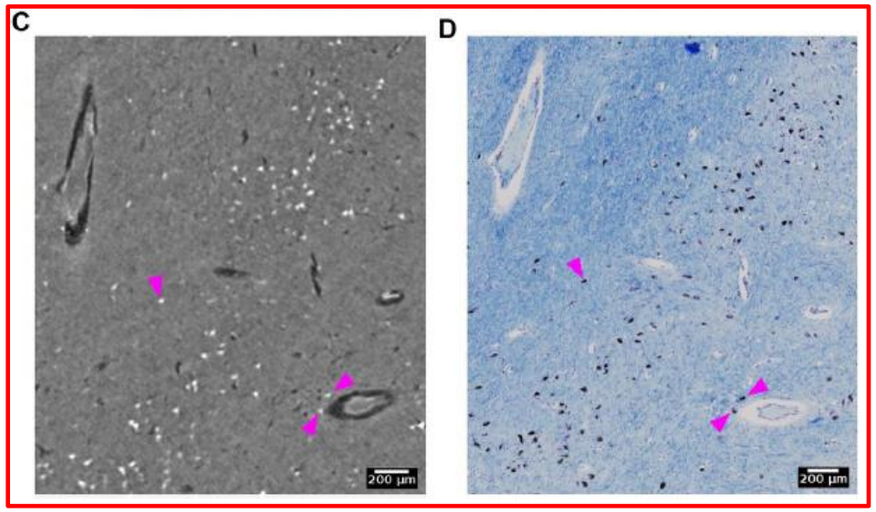
- Normal skin
- Nevus
- Seborrheic keratosis
- Basal cell carcinoma
- Melanoma in situ
- Invasive melanomas





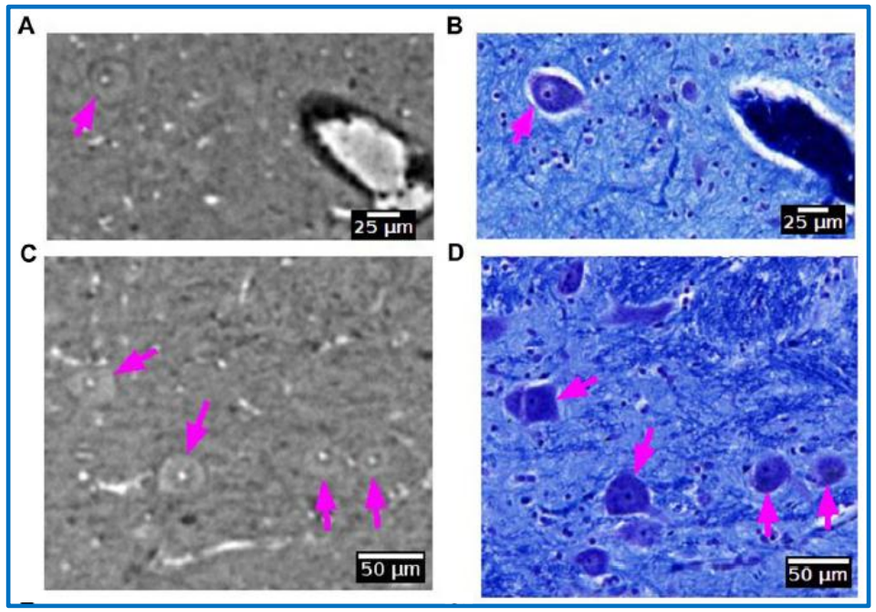
G. Saccomano et al. Skin Res. Technol. 30:e13801 (2024).

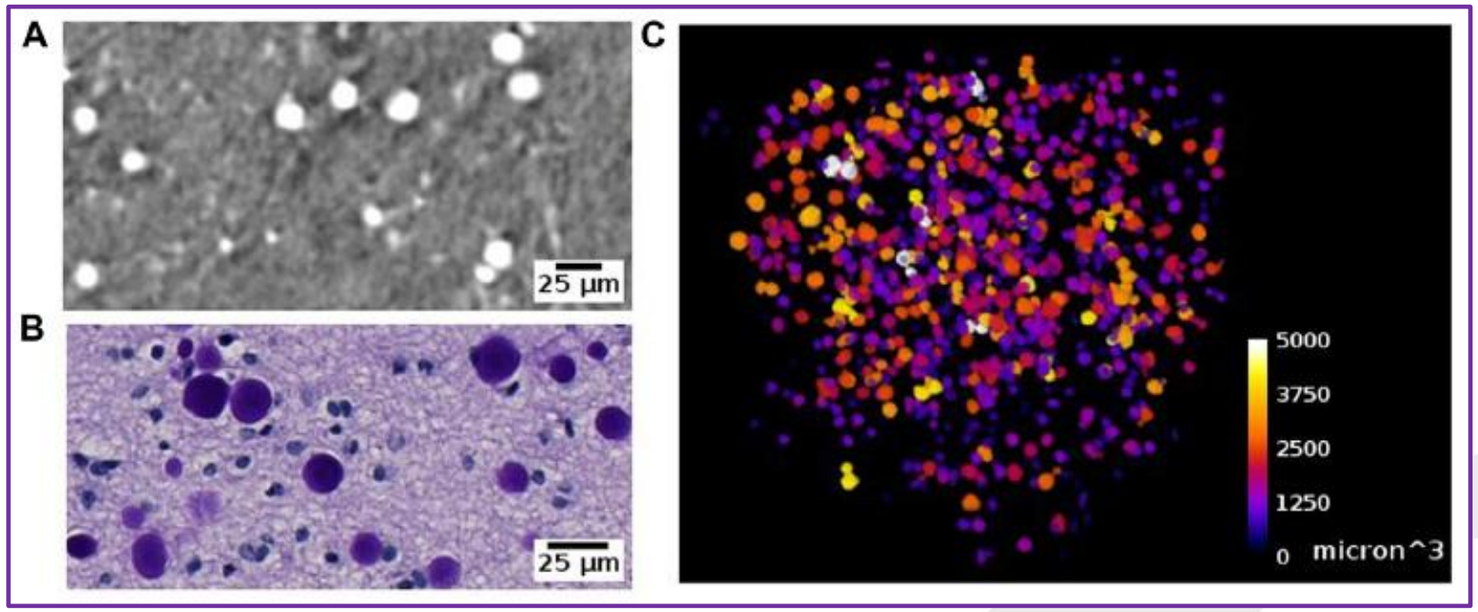
Brain tissue morphology



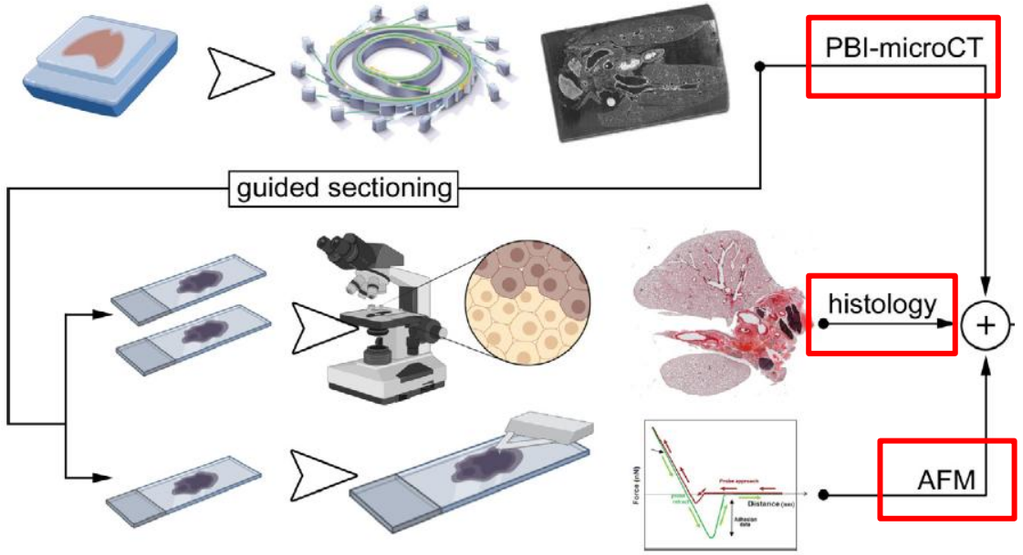
- ✓ Human unstained brain.
- ✓ Direct comparison between XPCT and histology.
- ✓ Evidence of neuromelanin (red panel).
- ✓ Detected neurons (blue panel).
- ✓ Visible corpora amylacea (violet panel).

J.Y. Lee et al. Frontiers in Physics 11:1335285 *(2023).*

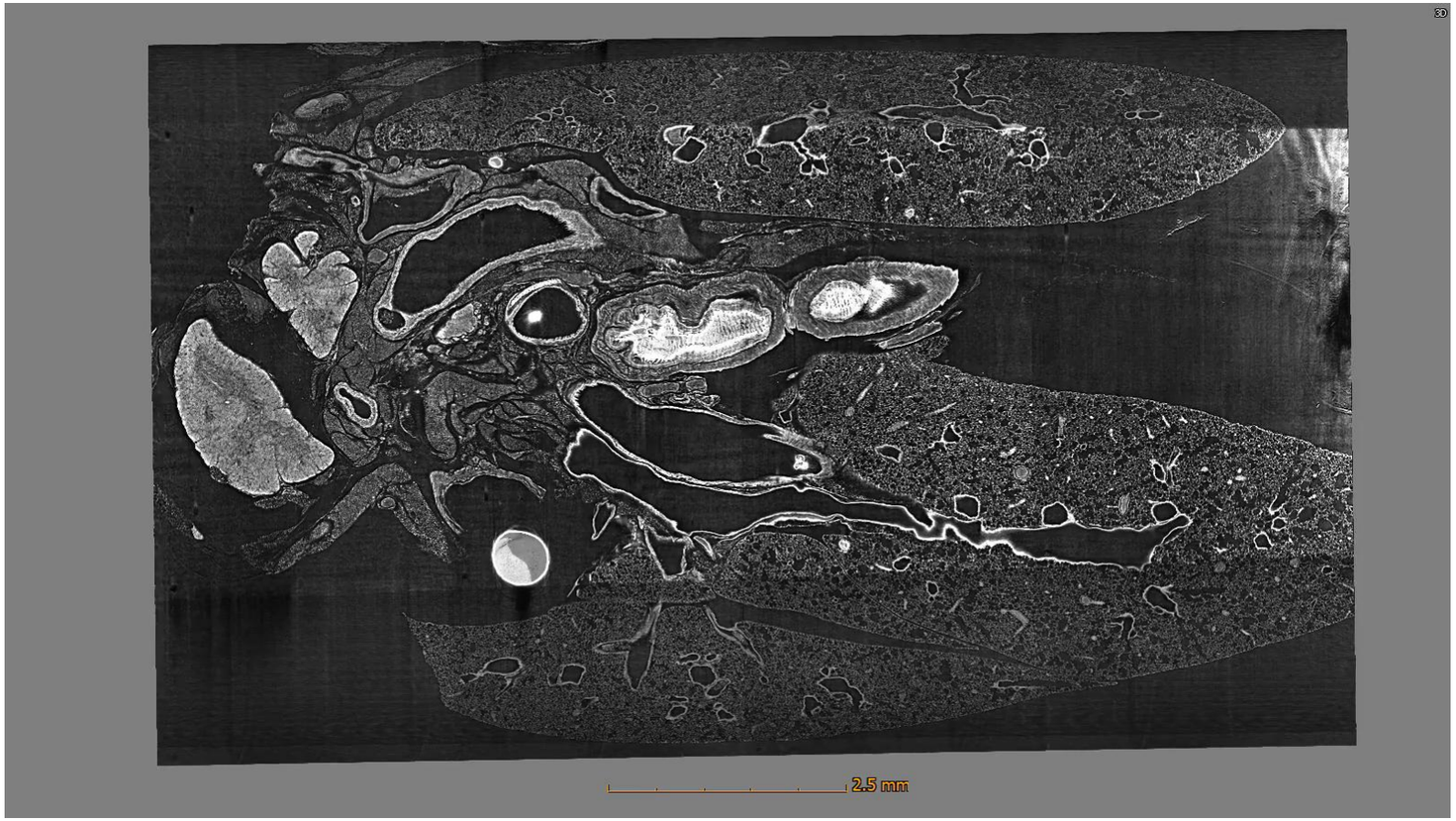




Multi-modal imaging of pulmonary fibrosis



L. D'Amico et al. Computers in Biology and Medicine 169, 107947 (2024).

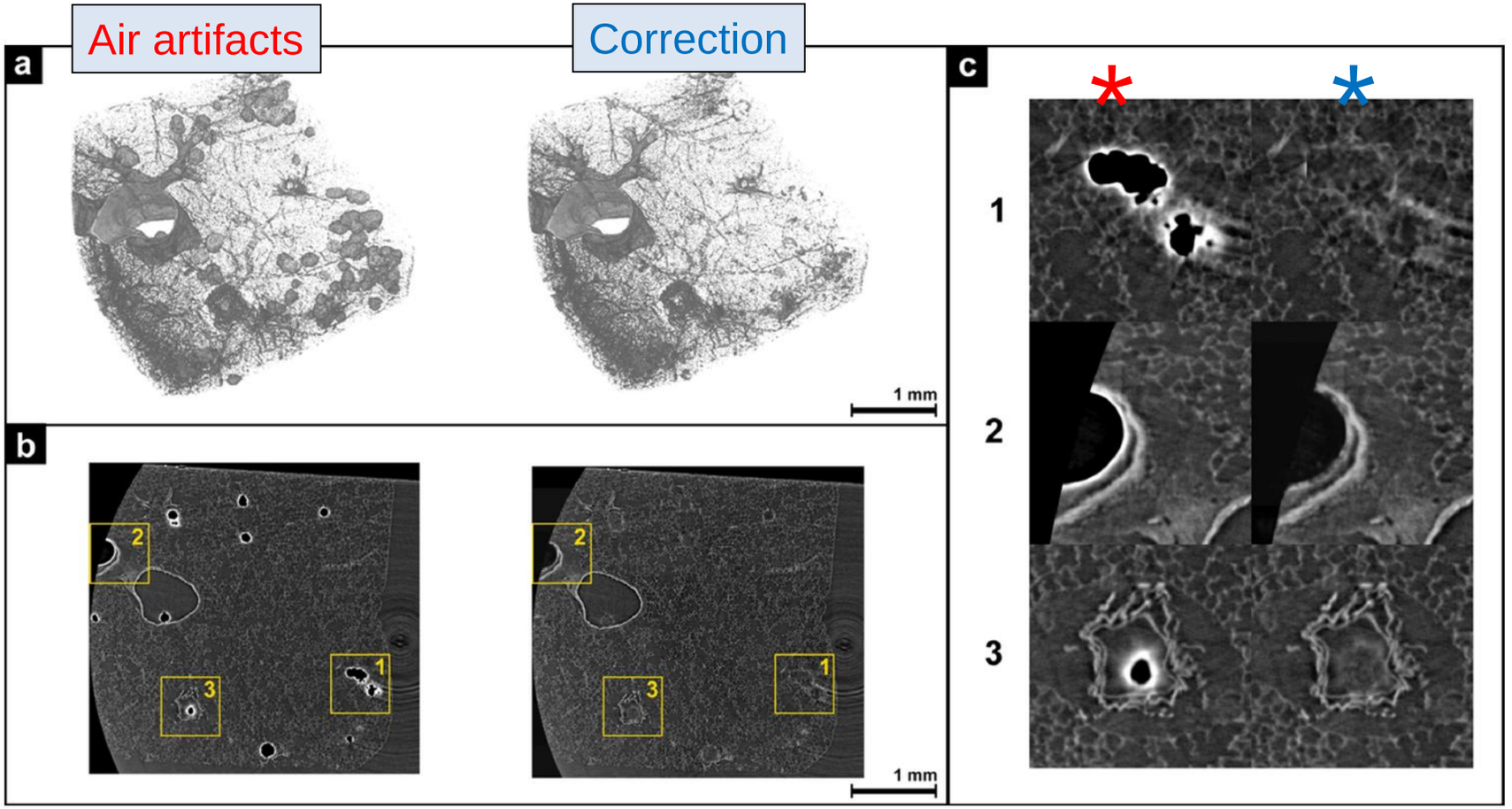


Video: Dr. Lorenzo D'Amico

Air artifacts suppression by machine learning

Air inclusion might generate strong edge effects caused by the phase shift at the air tissue / paraffin interface.

pix2pix-cGANs for translating a 3D cube with air artifacts (source) to a 3D cube without air artifacts (target).



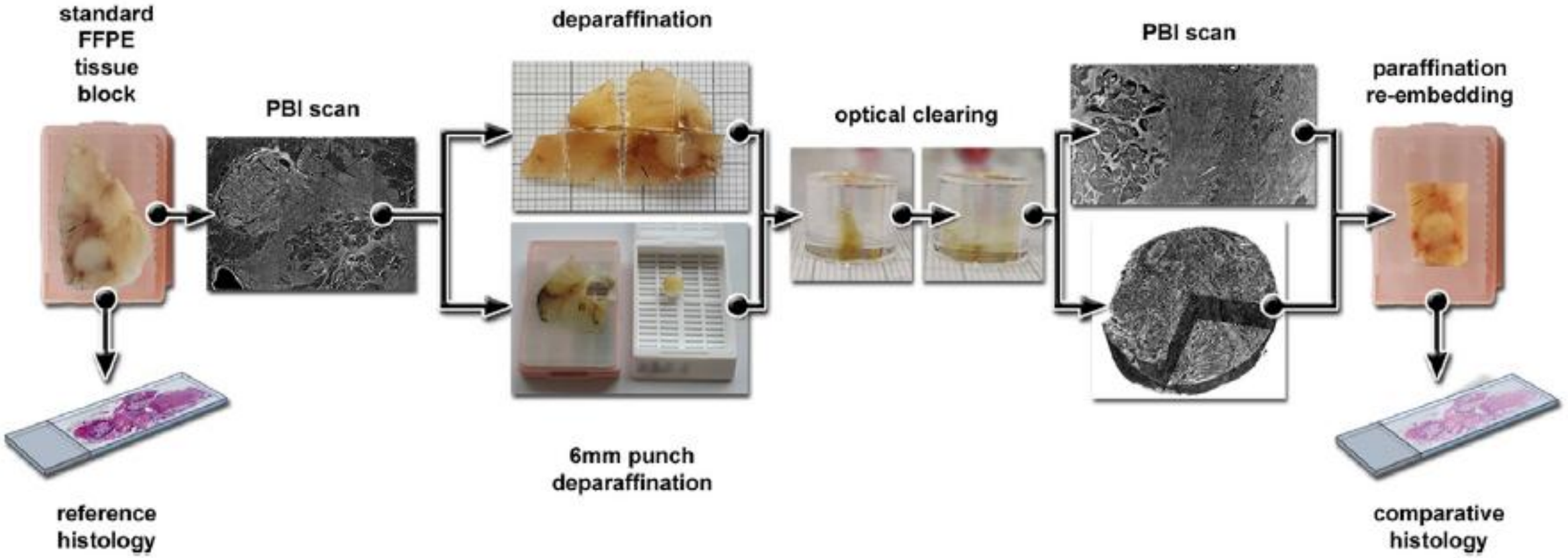
1. Air artifacts within the lung parenchyma are replaced with plausible lung tissue structures.

2. Air artifacts in a large vessel are reduced mainly in edge intensity.

3. The artifact in a smaller vessel is replaced with lung tissue.

M.M.R. et al. Journal of Synchrotron Radiation 32 (2025).

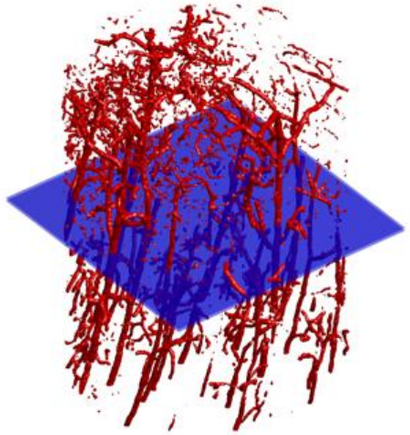
Sample preparation: FFPE tissue blocks or optical clearing

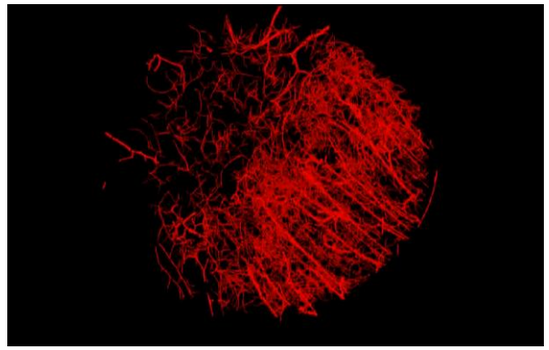


M.M.R. Sagar et al. Front. Phys 12:1433895 (2024).

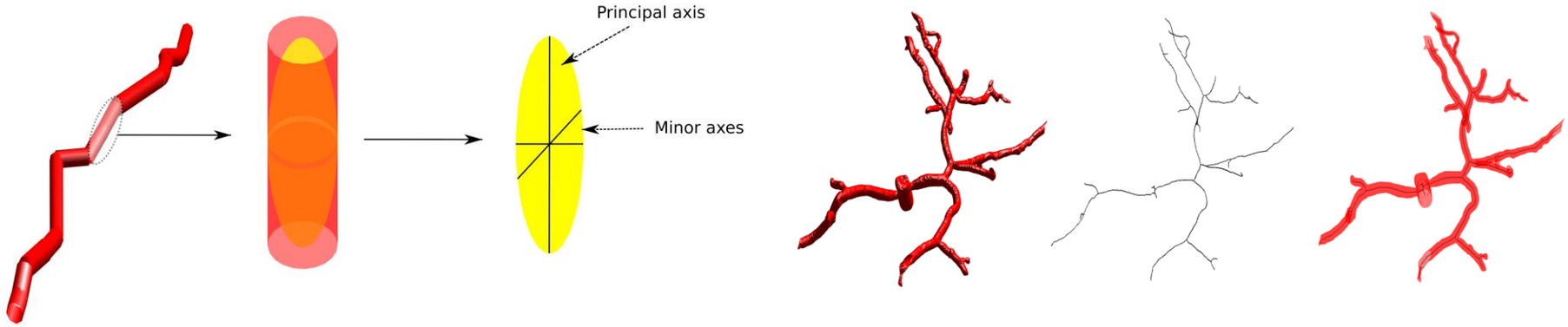
Imaging of microvascular network in nervous system

Intercardiac perfusion with black Indian ink





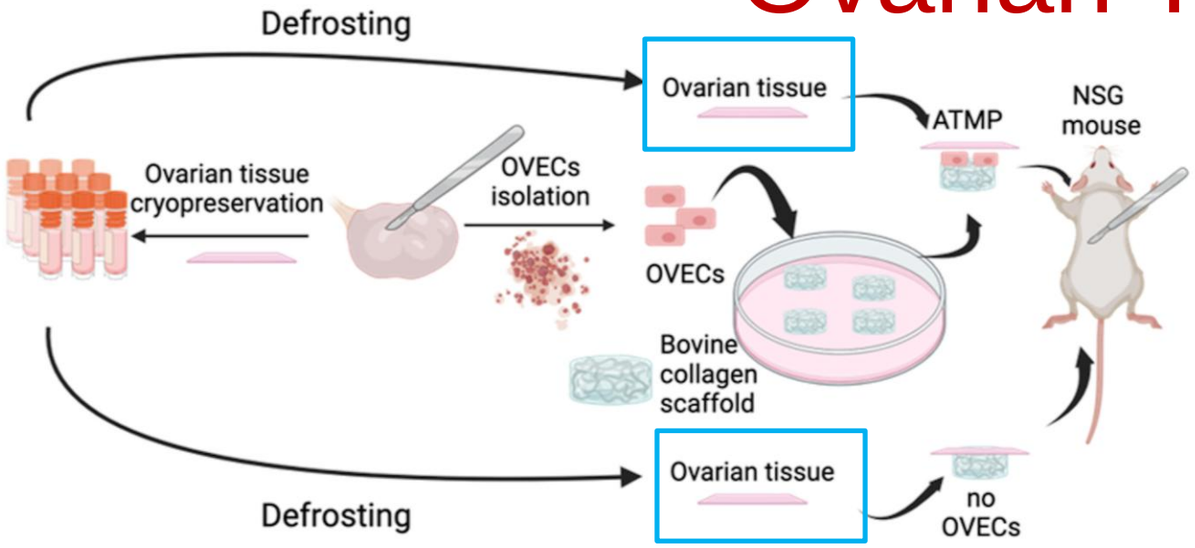
It has been developed an imaging protocol for evaluating the microvascular network in central and peripheral nervous system of rats exposed to chronic chemotherapy treatment.

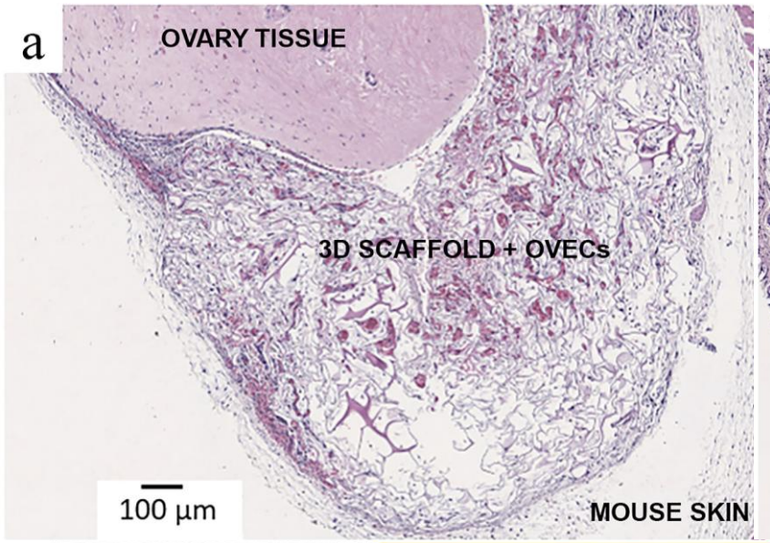


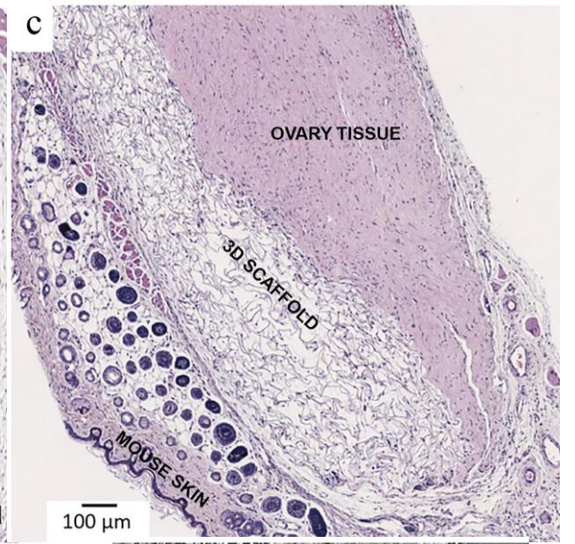
Vascular network parameters: vascular density, vessel diameter, tortuosity and branching.

A.G. Zippo et al. Journal of the Peripheral Nervous System 29(4), 537-554 (2024).

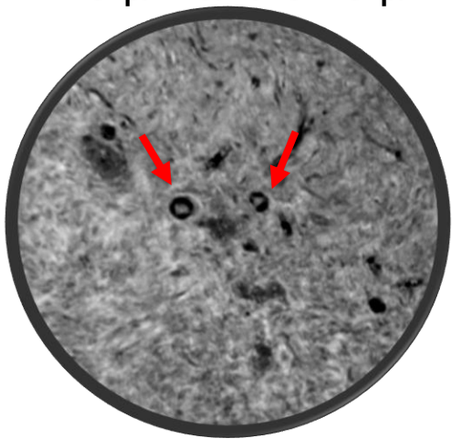
Scaffold-based strategy for Ovarian Tissue Transplantation

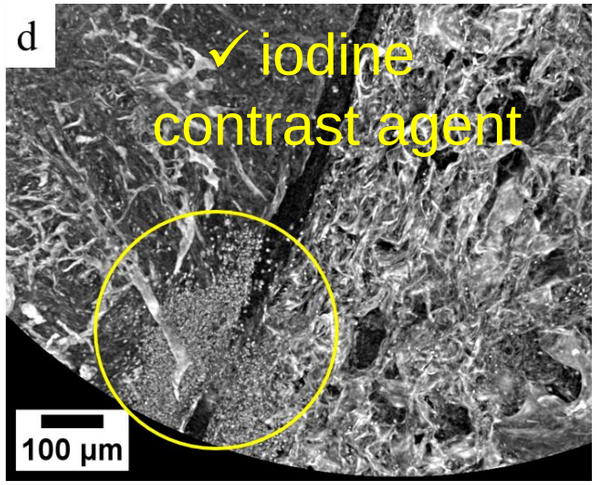


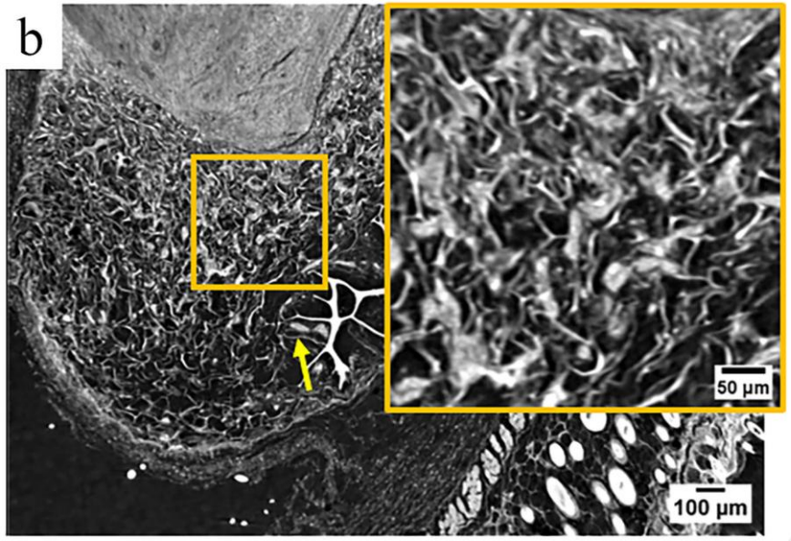


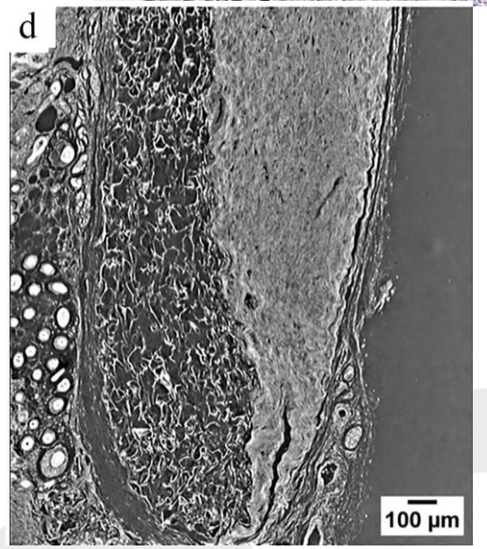


Visible primary / primordial follicles
Ø 44.5 µm and 32.5 µm







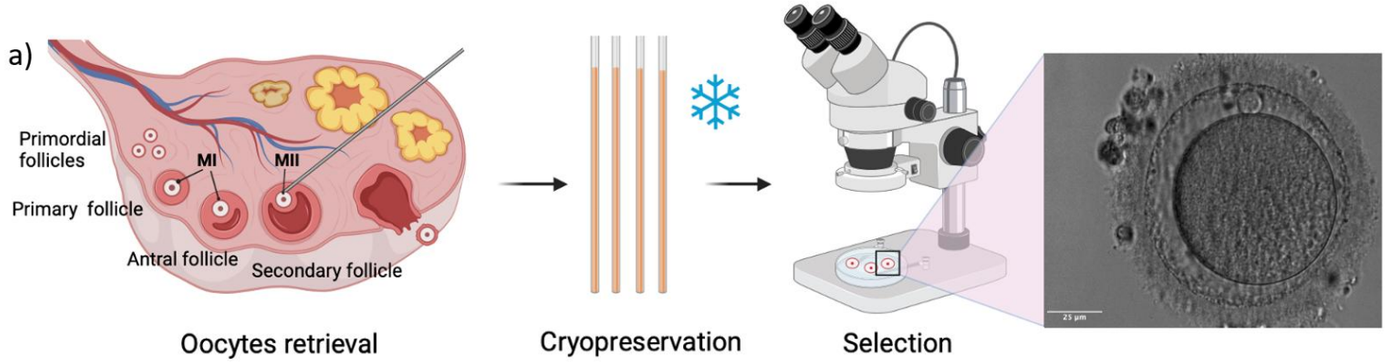


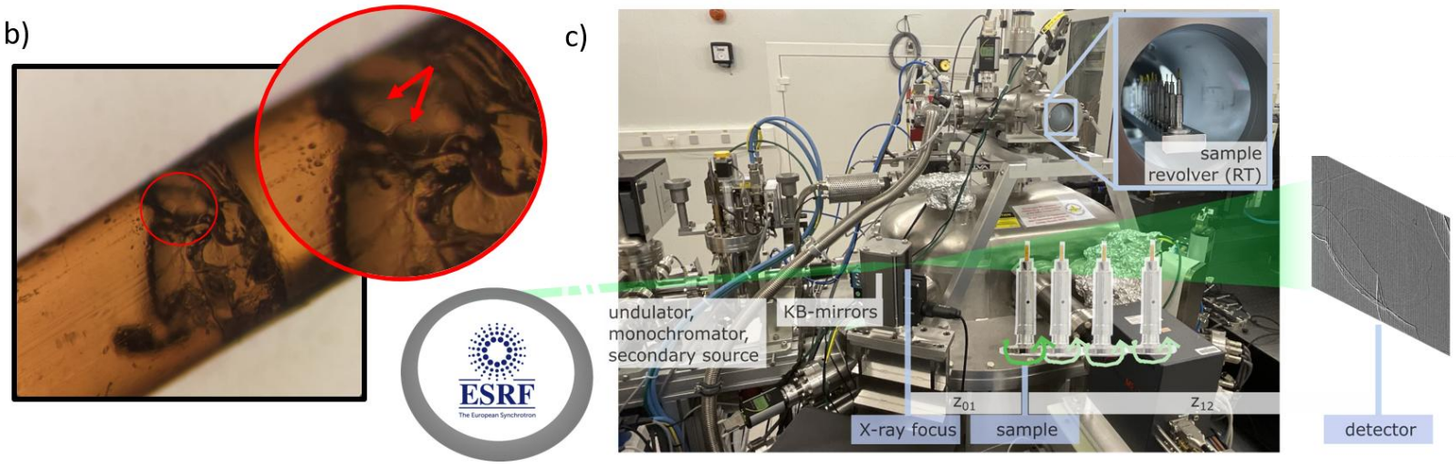
M. Spazzapan et al. Bioactive Materials 50, 305-321 (2025).

X-ray Nano-holotomography (XNH) of human oocytes

***Post-Thaw analysis**: X-ray nano-imaging conducted at room temperature following cooling/ warming protocols.*

Collaboration with Burlo hospital in Trieste: Dr. L. Pascolo, C. Tufoni

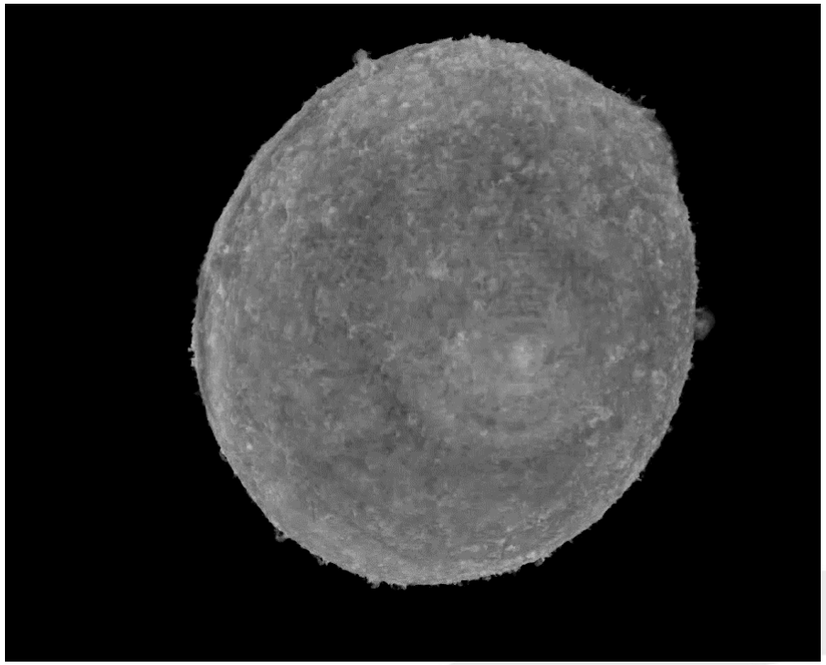




ID16A setup

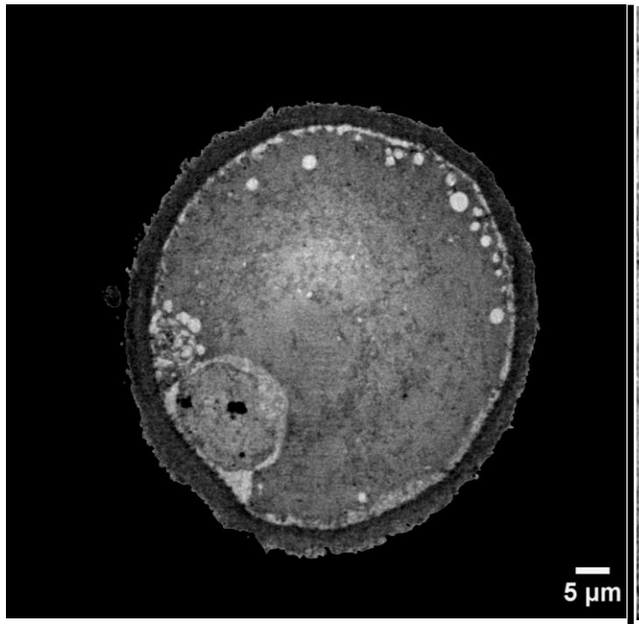
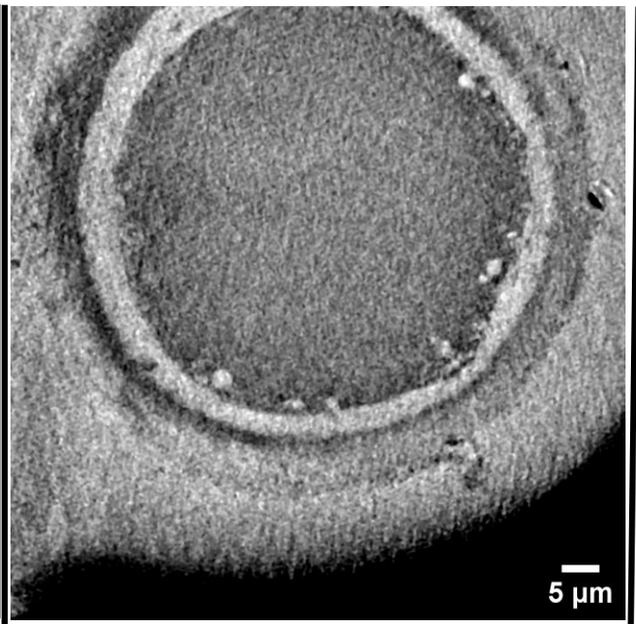
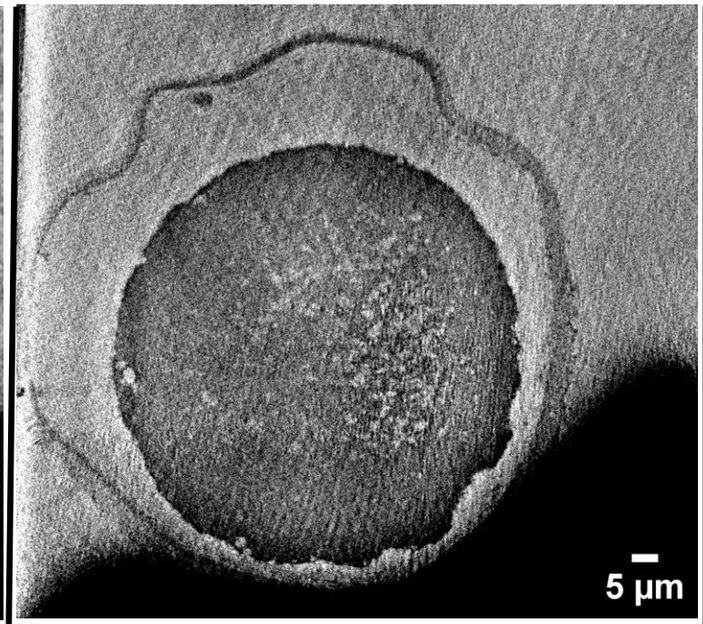
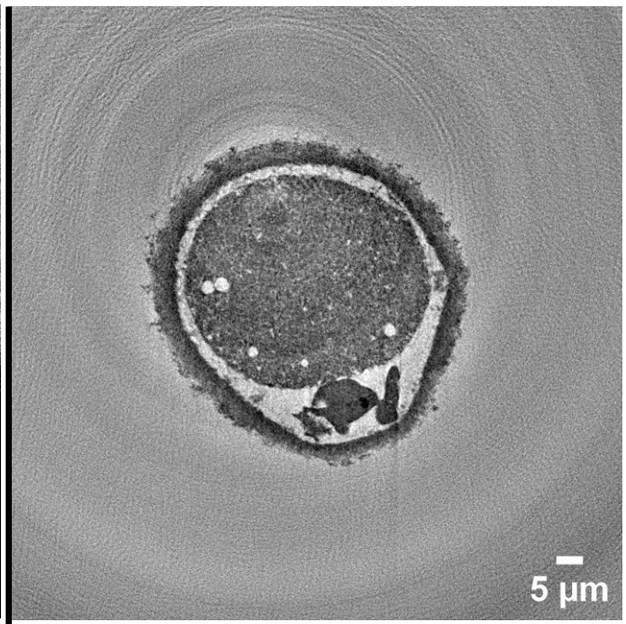
✓ To validate the 3D morphology non-destructively

Voxel size: 70 nm x 70 nm x 70 nm



E. Longo et al. Materials & Design 266, 116065 (2026).

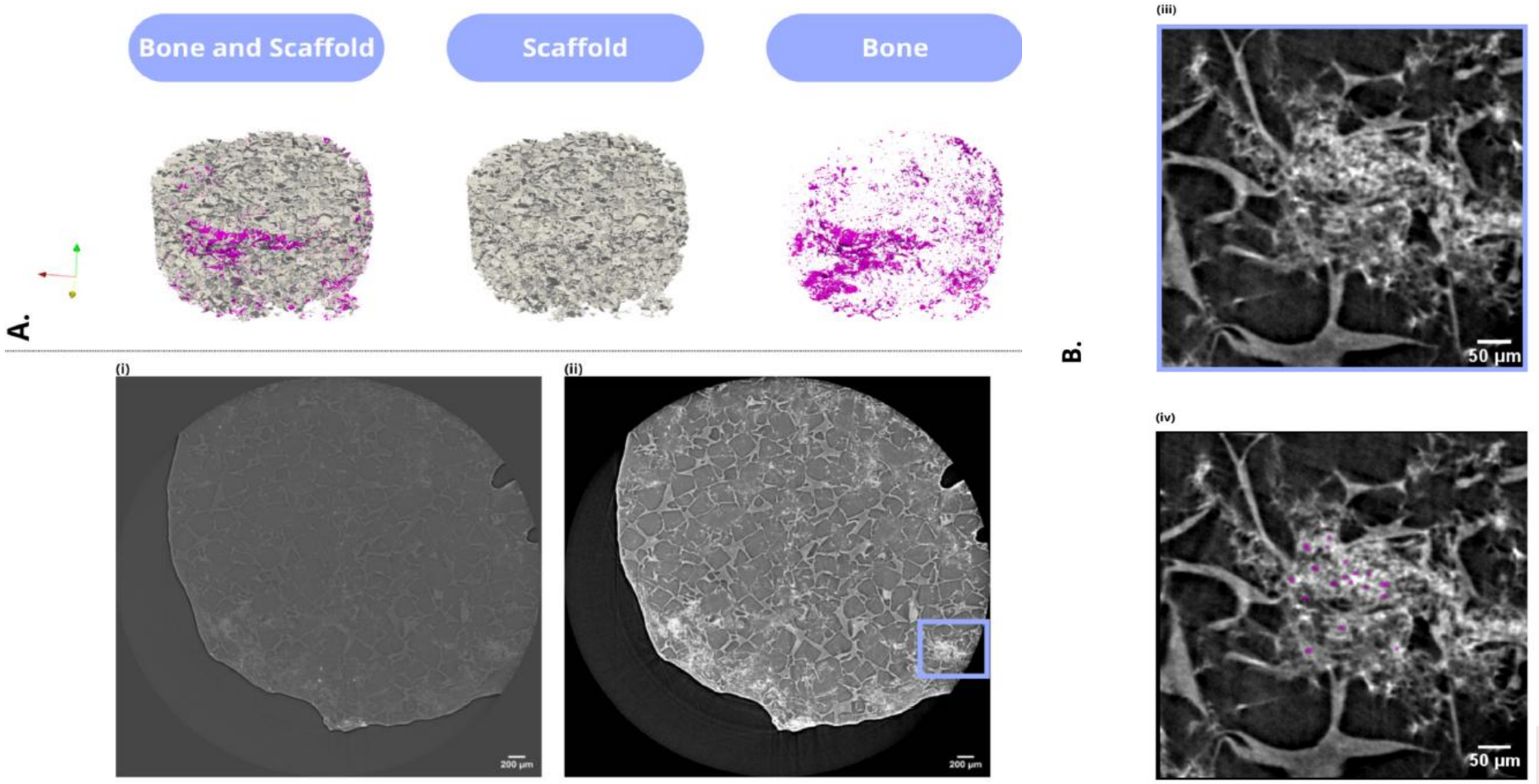
Well-preserved vs Cryo-injured oocytes

Optimal	CRYO-INJURED OOCYTES		
			
Preserved features: • Spherical shape • Well defined polar body (PB)	• Missing PB	• Irregular ZP edges • Expanded PVS • Ooplasm lower edge jagged	• Oval shape • Fragmented PB

E. Longo et al. Materials & Design 266, 116065 (2026).

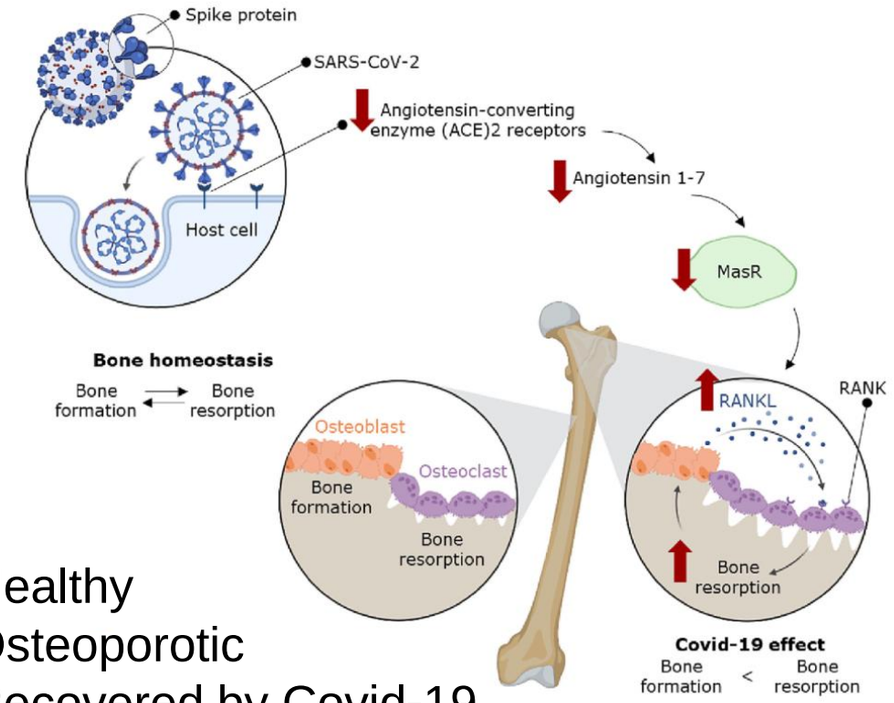
Sustainable silk fibroin scaffolds

- Silk fibroin scaffolds support bone regeneration.
- Synchrotron imaging was combined with AI to quantitatively characterize scaffolds microarchitecture.



G. Dei Rossi et al., Biomaterials Advances 181, 214658 (2026).

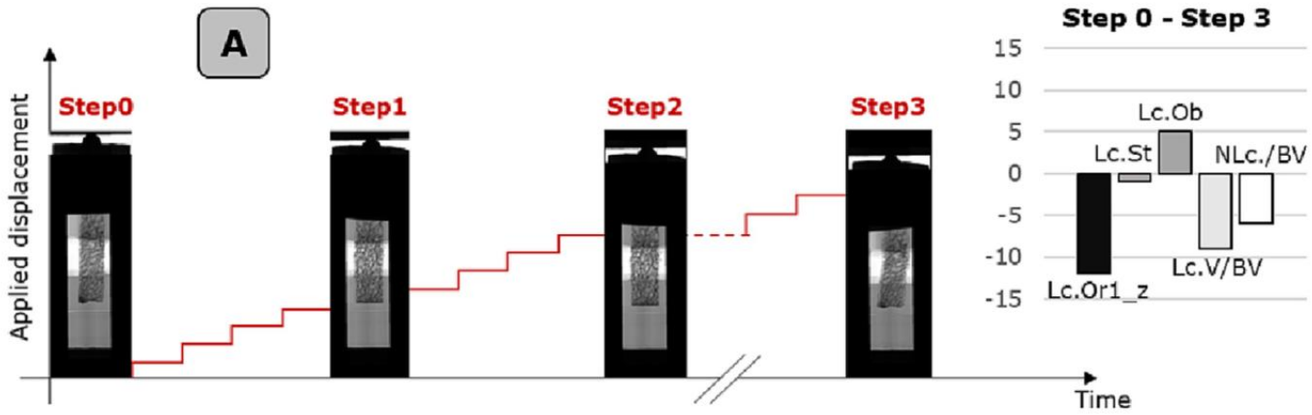
Osteoporosis and Covid-19 correlation

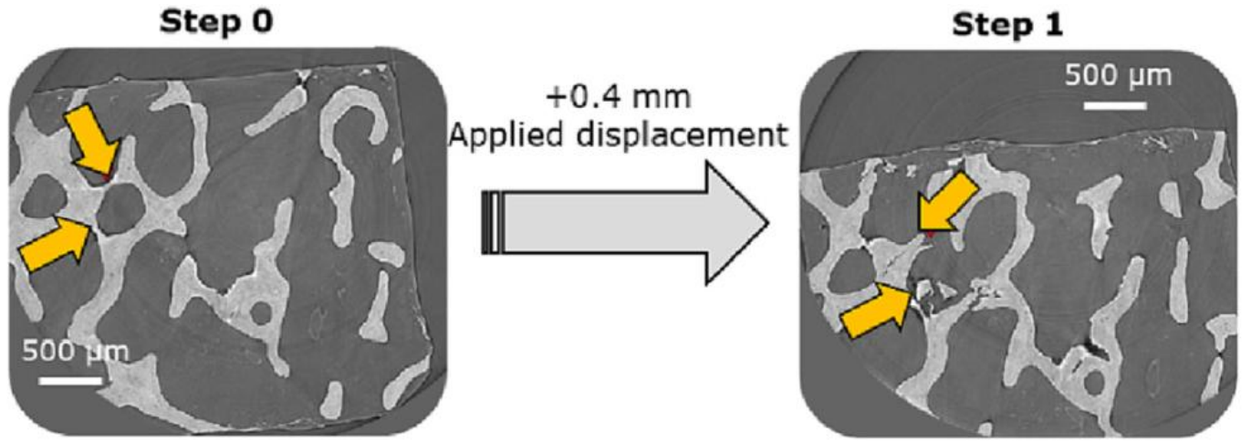


1. Healthy
2. Osteoporotic
3. Recovered by Covid-19

- AI-based tool was used to analyze osteocyte lacunae morphology.
- Osteoporosis signs can be detected at the micro-scale through changes in osteocyte lacunar features and Covid-19 worsens micro-scale porosities similarly to osteoporotic conditions.

In-situ mechanical testing by XPCT

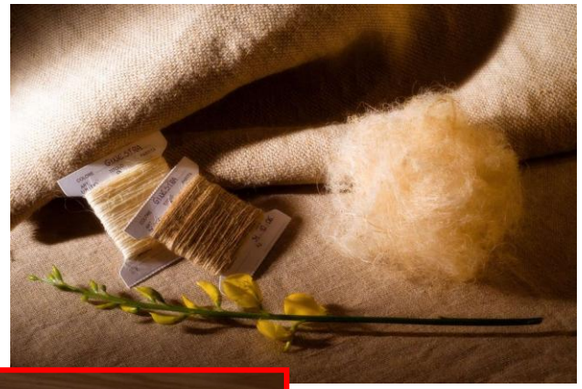




F. Buccino et al. Materials & Design 231, 112087 (2023).

Eco-sustainable wound dressing

Courtesy: Prof. T. Cerchiara, Prof. C. Cappadone, Prof. E. Malucelli, Dr. F. Rossi University of Bologna; Dr. M. Fratini, CNR-Nanotec, Prof. G. Chidichimo, University of Calabria.



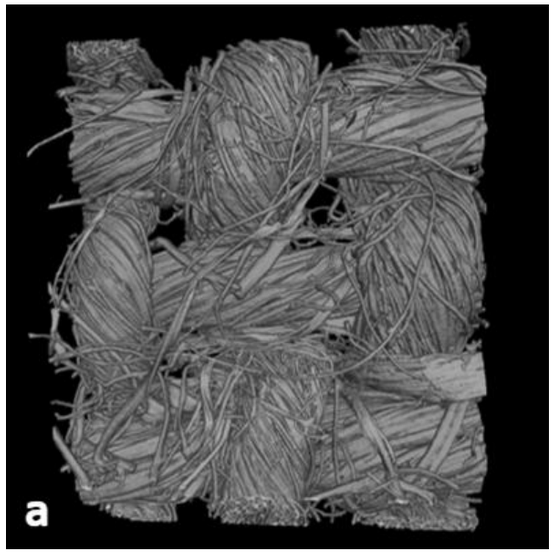
- Cotton cultivation is environmentally demanding due to the use of pesticides and water.

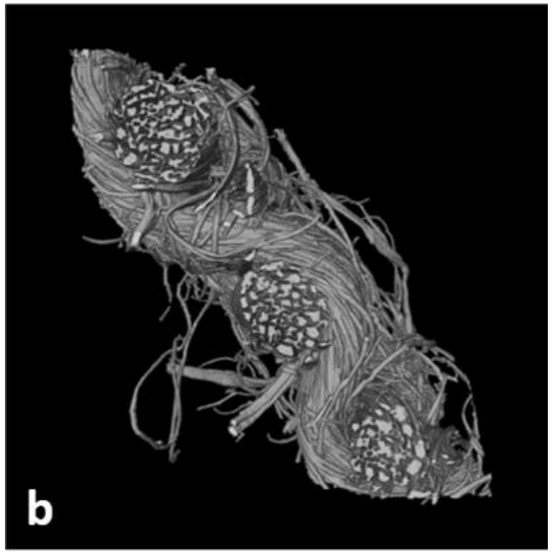
✓ Spanish broom (SB) -> sustainable and biodegradable.

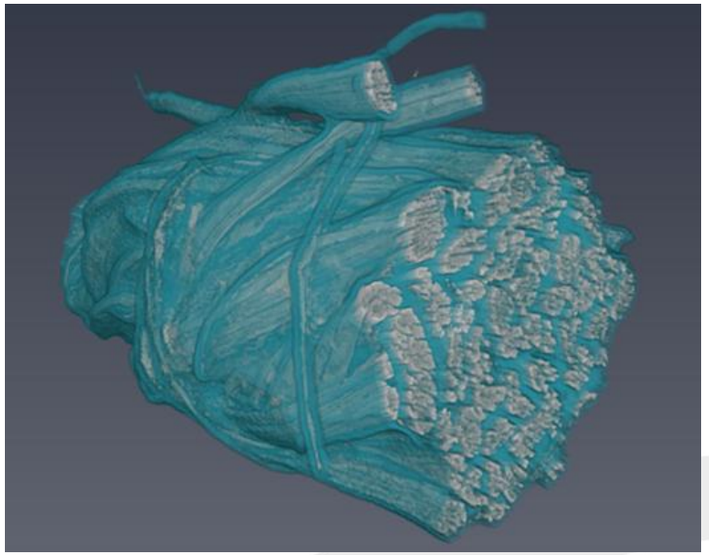
✓ SB grows spontaneously in the Mediterranean.

✓ SB fibers may be used for clothes or pharmaceutical preparations (wound dressings).

✓ Morphological characterization: dry / wet wound dressing.





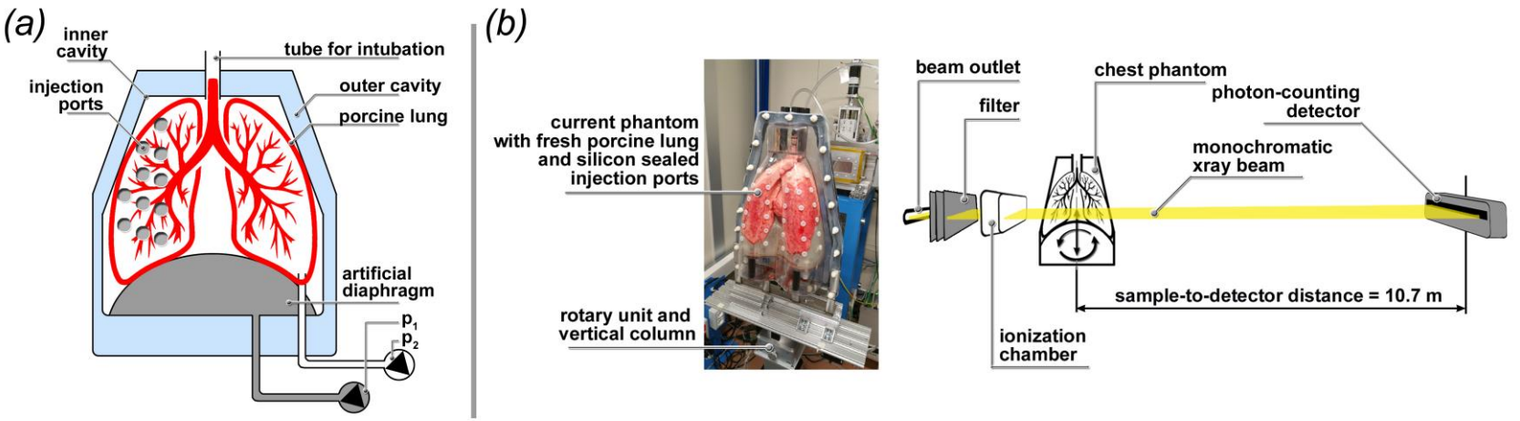


V. Sallustio et al. International journal of biological macromolecules 272, 132883 (2024).

Low dose XPCT lung imaging

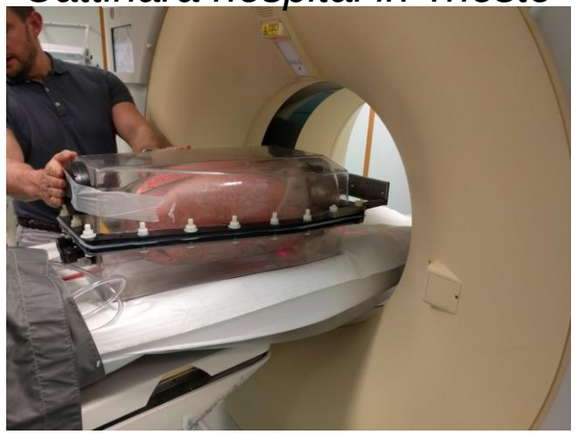
- Aim: to evaluate the potentials of propagation-based lung CT for early detection of **lung cancer** and **idiopathic fibrosis in humans**.
- Hydra X-Counter SPC, 100 µm pixel size (Ef. pixel size 67 µm).
- Monochromatic E= 40 keV.
- Air entrance dose ~

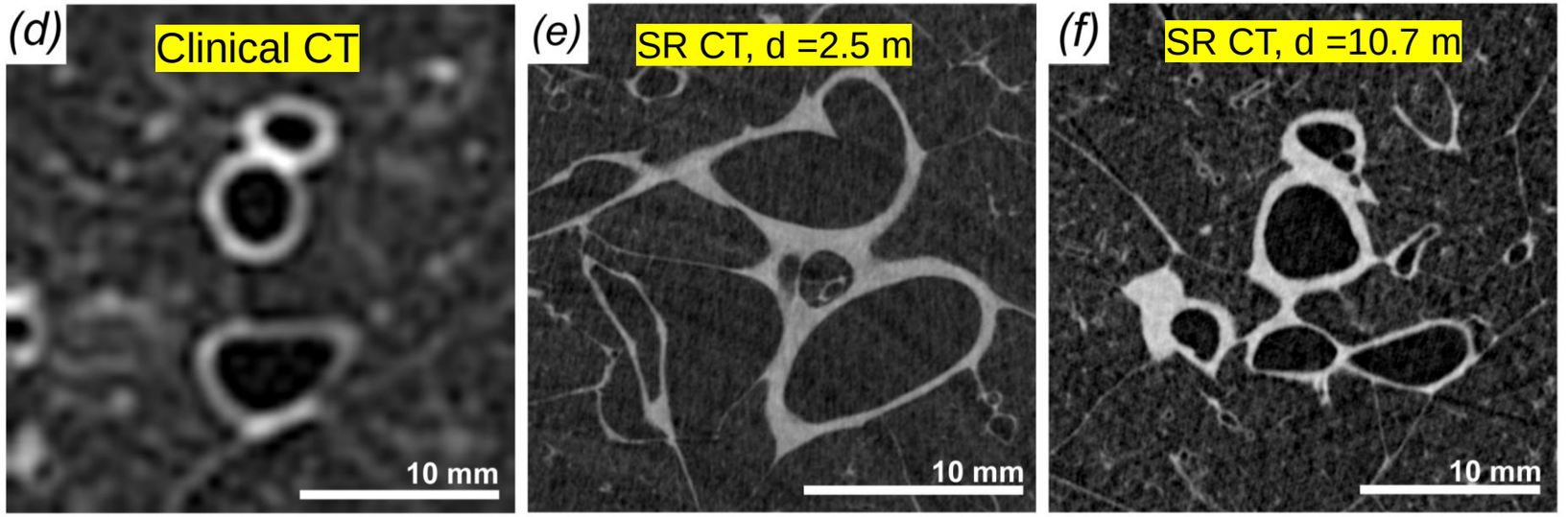
13 mGy XPCT Vs 33 mGy clinical.



Clinical CT (voxel 450x450 x900 μm^3) shows similar details rather blurred.

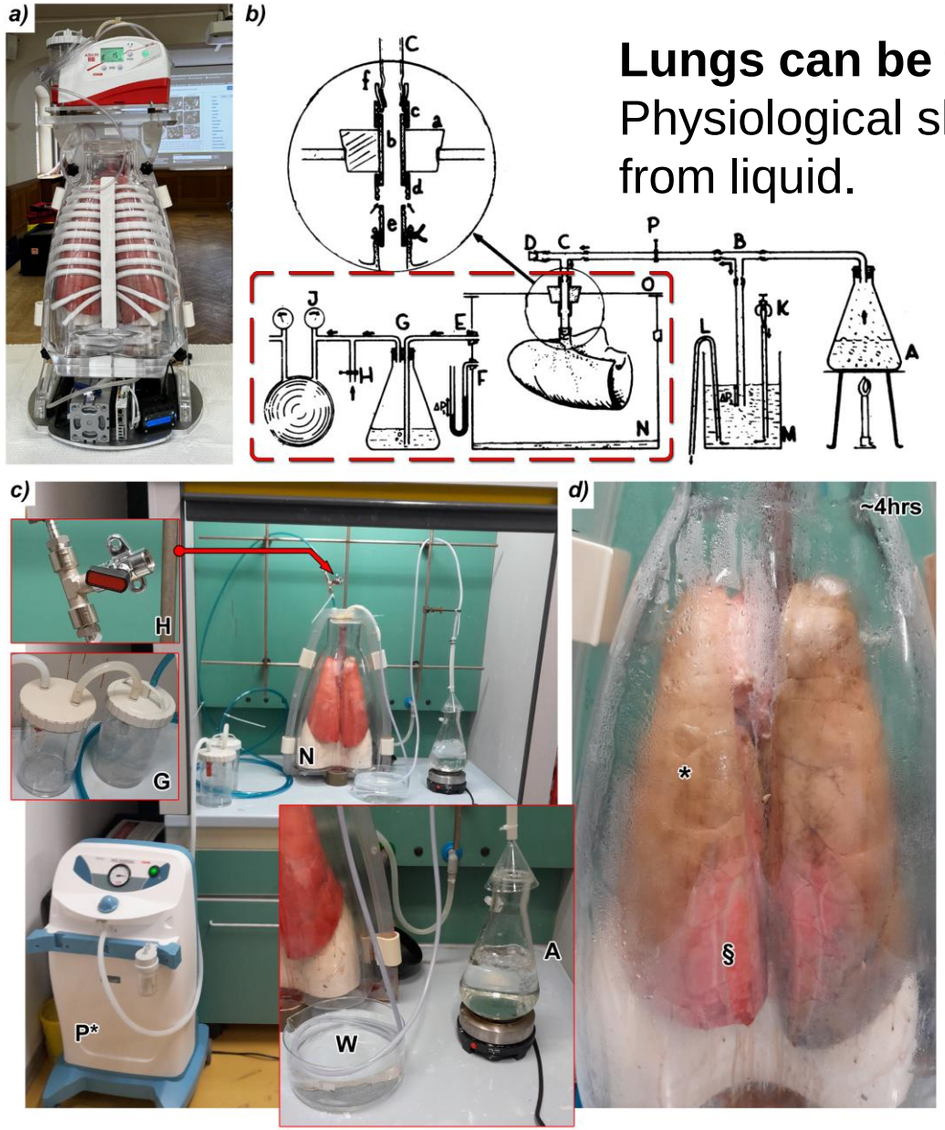
Cattinara hospital in Trieste



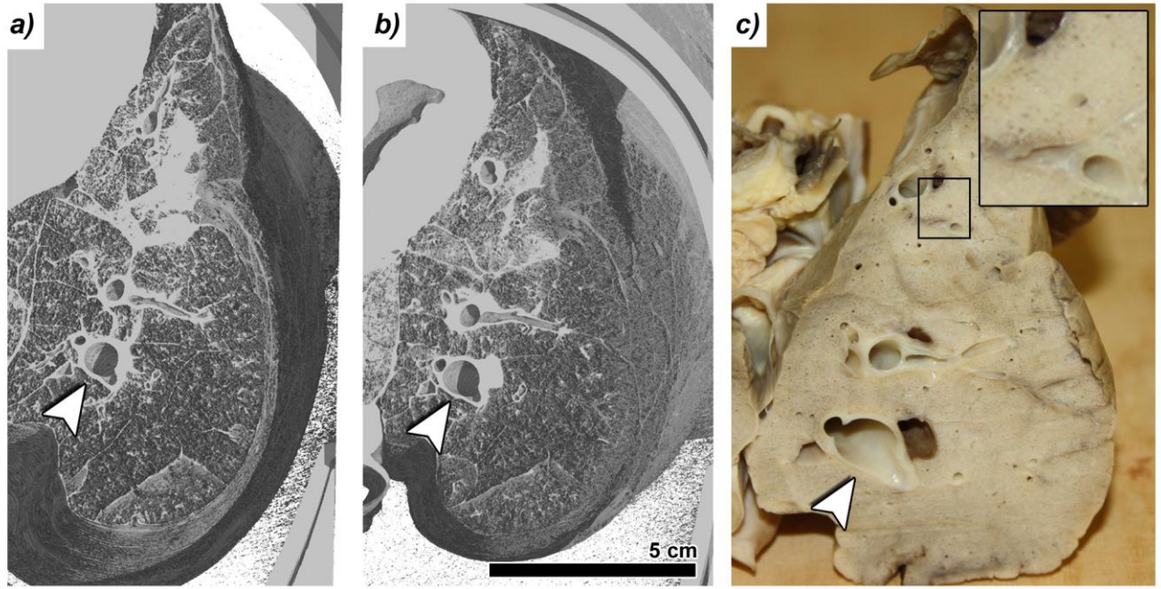


J. Albers et al. Scientific Reports 13:4788 (2023).

Vapor fixation enables imaging validation



Lungs can be fixed with formalin vapor under negative pressure
Physiological shape is maintained while the airways remained free from liquid.

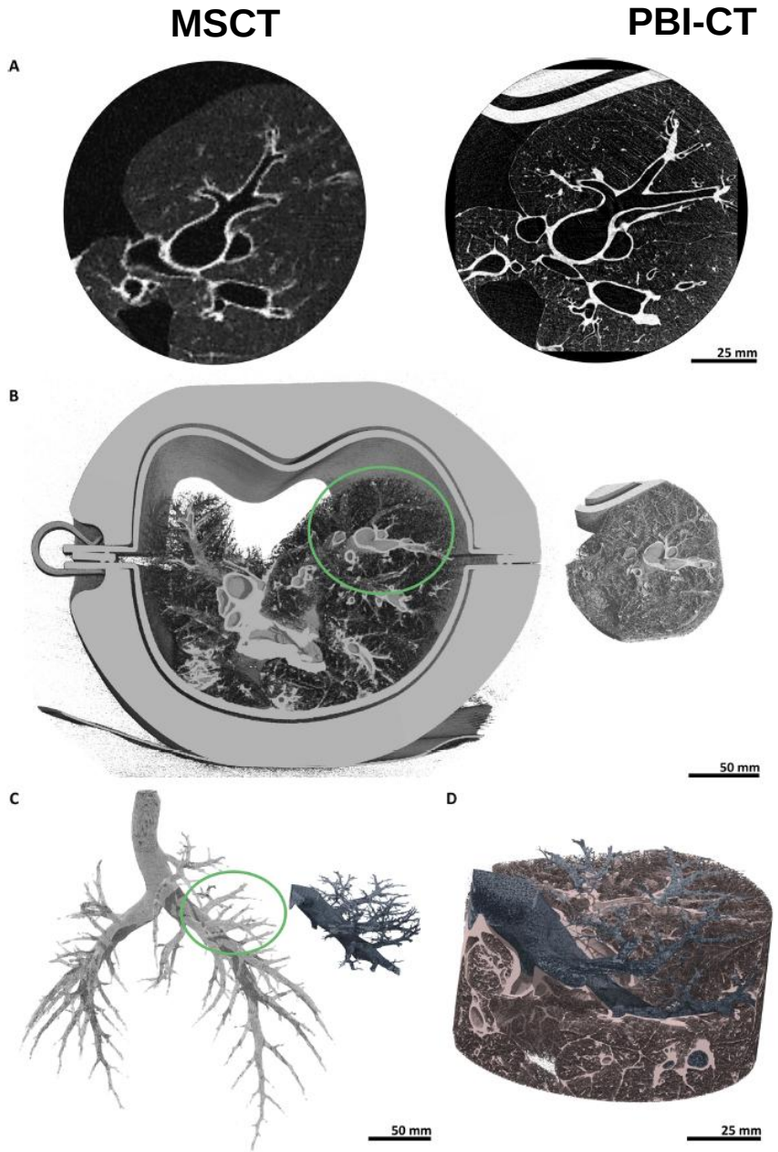


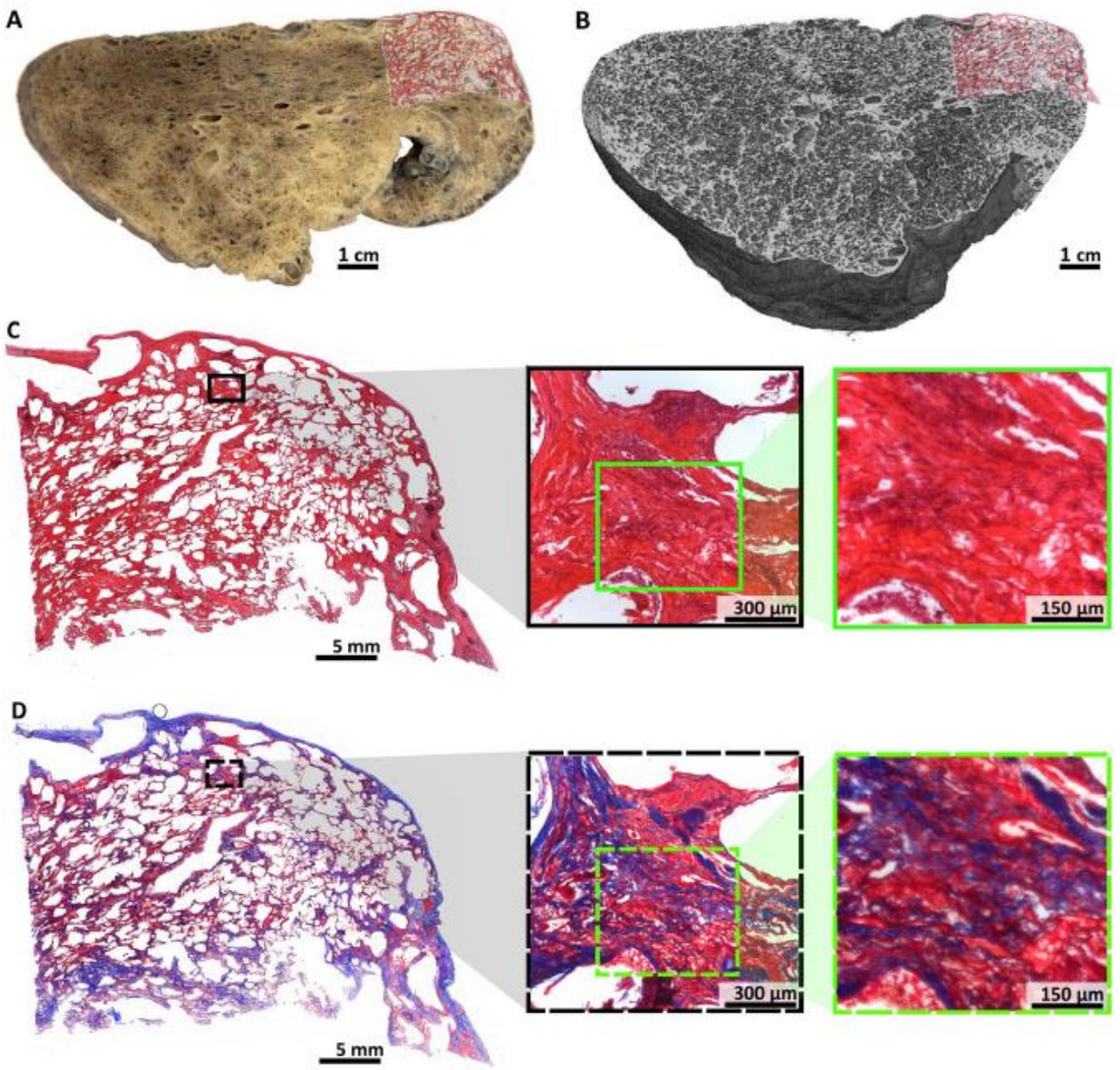
Phase contrast CT of the fresh lung (a) and the vapor fixed lung (b) show similar image quality
The macroscopic image of the fixed lung shows that the fixation was successful, with good preservation of the porous nature of the lung and the absence of liquid in the bronchi.

C. Dullin et al. Scientific Reports 15, 36475 (2025).

Microstructural pulmonary imaging

Visualization of peripheral lung structures in a porcine model





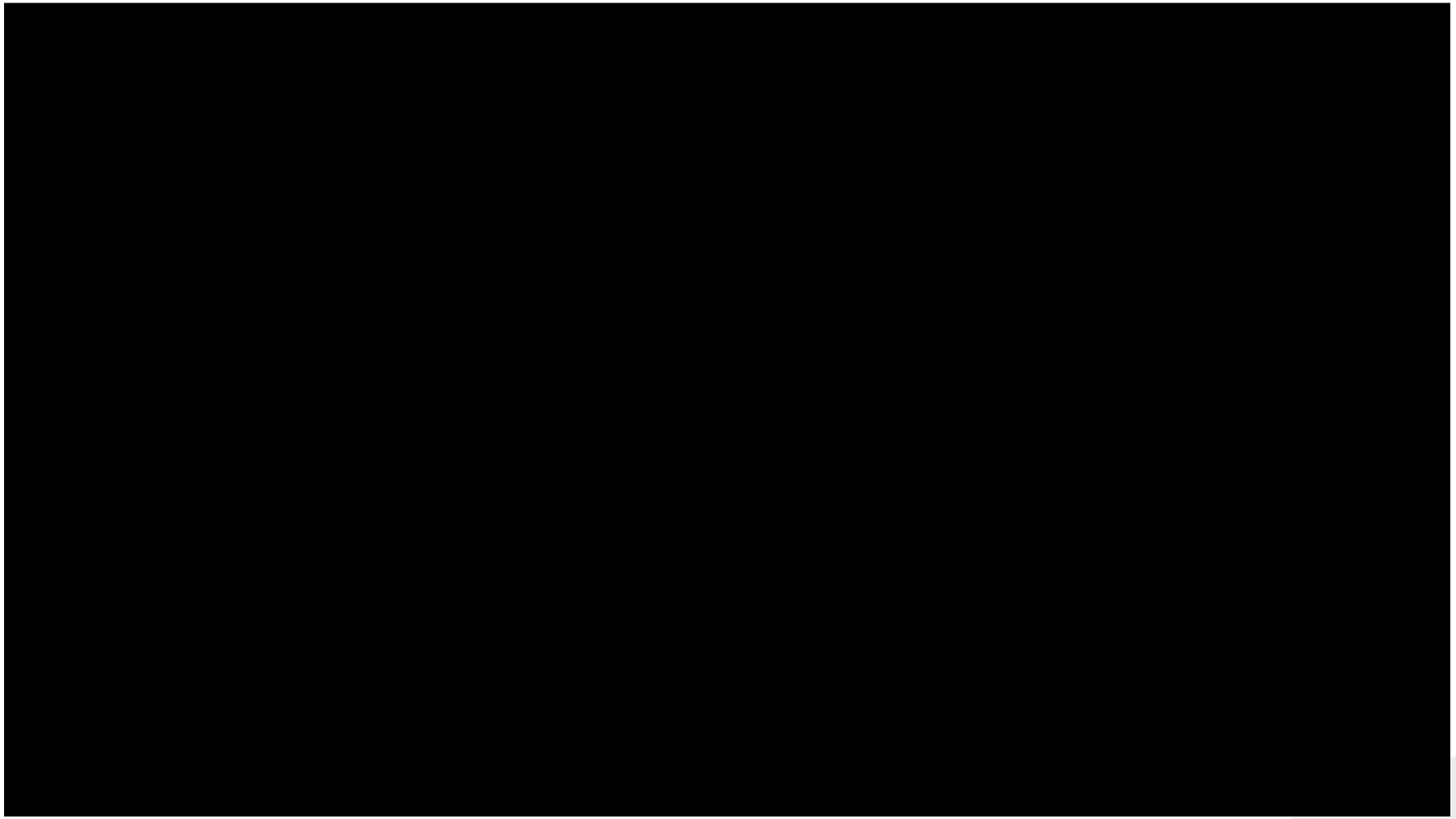
LAMBDA Detector: eff. pixel size 38 µm

Detection of idiopathic pulmonary fibrosis in a human sample

C. Benke et al. Respiratory Research 27:105 (2026).

Correlation: PBI,Bronchoscopy and MSCT

Video: Dr. Claudia Benke, Dr. Christian Dullin



C. Benke et al. Respiratory Research 27:105 (2026).

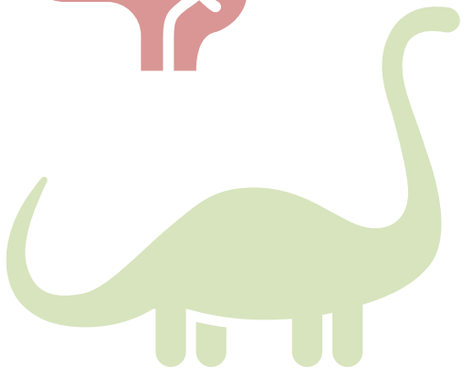
Elettra 2.0 upgrade: SYRMEP- Life Science

Broader Energy Range (Mono): 10 – 120 keV → New Research Applications
Beam size: 210 x 8 mm² (I stage), 280 x 12.5 mm² (II stage)

1. Life science applications, tissue imaging and biomedical research

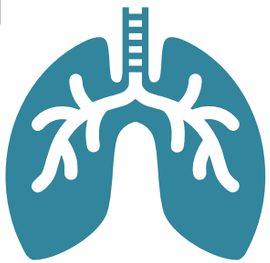
2. Pre-clinical and small animal imaging

3. Materials Science, Geology, Cultural Heritage and Paleontology



4. 4D Imaging, In-situ and In-operando

5. In- vivo (patients) low-dose lung CT



Open to collaborations

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UNI EN ISO 45001:2023
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Thank you!

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