

14th European Conference on Mathematical & Theoretical Biology
University of Graz, Austria

Modelling the emergence of connective tissue architecture

P. Chassonnery, J. Paupert, A. Lorsignol, C. Sévérac, M. Ousset,
L. Casteilla, D. Peurichard

16th July 2026



1 Construction of the model

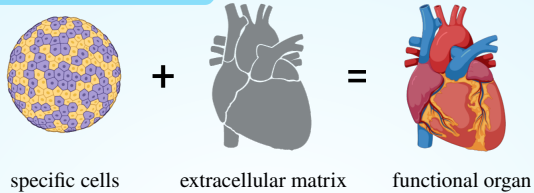
- Biological context
- Objective and hypotheses
- Concept proof
- 3D mechanistic agent-based model

2 Results

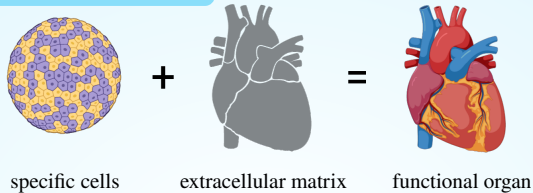
- Self-organization of the ECM
- Segmentation of cell clusters (lobules)
- Morphological classification of these lobules
- Parametric analysis of the fit with *in vivo* data

3 Conclusions

Link between architecture and function



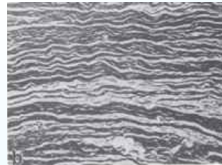
Link between architecture and function



Role of the extracellular matrix (ECM)



skin : basketweave pattern



scar : aligned pattern

How is the architecture of biological tissues formed ?

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Main hypotheses :

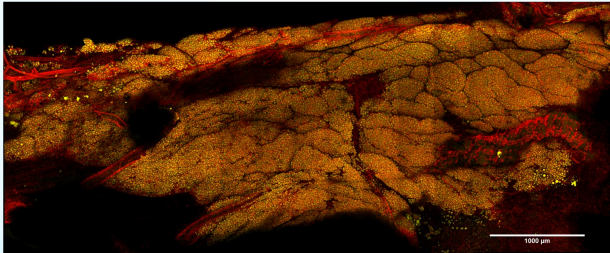
- 1 The architecture of a tissue is *emergent*.
- 2 The architecture of a tissue is mainly determined by the *mechanical constraints* exerted by the *ECM*.

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Test case : the adipose tissue (ECM + adipocyte cells).





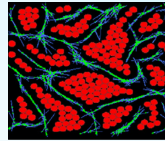
Journal of Theoretical Biology

Volume 429, 21 September 2017, Pages 61-81

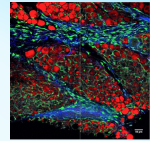


Simple mechanical cues could explain adipose tissue morphology

Peurichard et al, 2017



2D numerical
simulation



Adipose tissue slice
(Restore & ITAV)



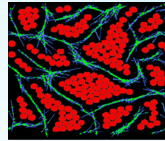
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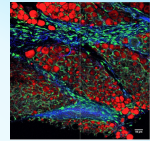


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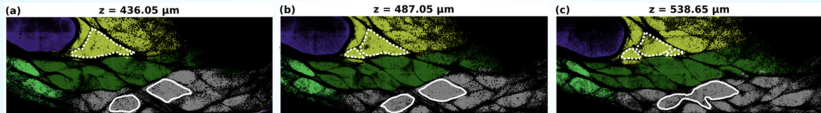
2D numerical simulation



Adipose tissue slice (Restore & ITAV)

Main limitation of this model : the 2D approach.

- Possible qualitative changes in fiber behavior.
- The 3D architecture of adipose tissue is more complex than what was previously understood from 2D images.



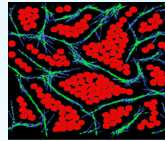


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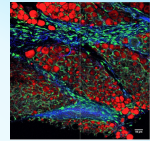


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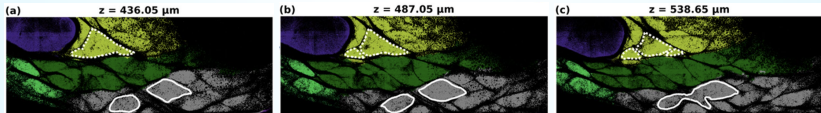
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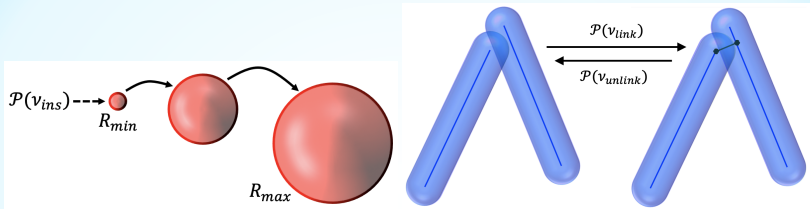
Expected challenges in 3D :

- costs (time et memory) of the simulations,
- data visualization (qualitative analysis),
- data segmentation (quantitative analysis).

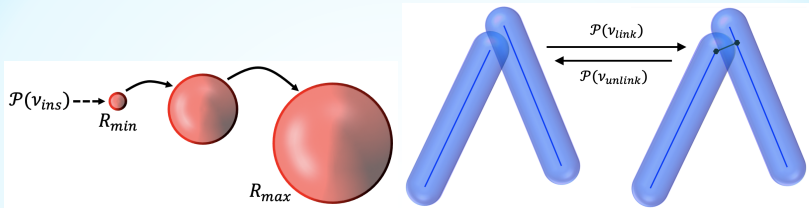
→ Two species :

- adipocytes $\simeq$ spheres
- ECM $\simeq$ network of rods connected by springs

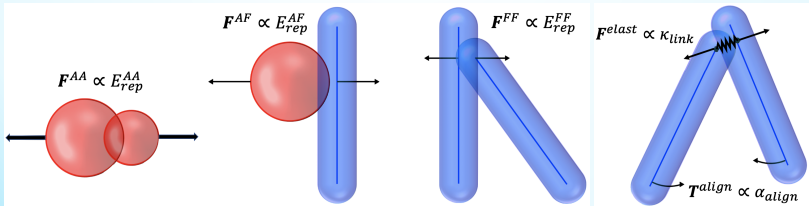
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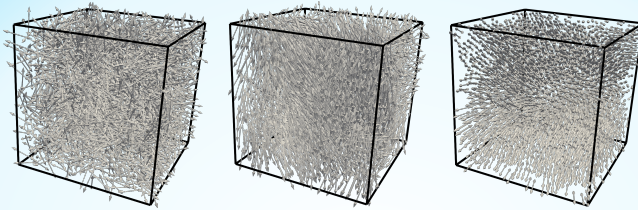


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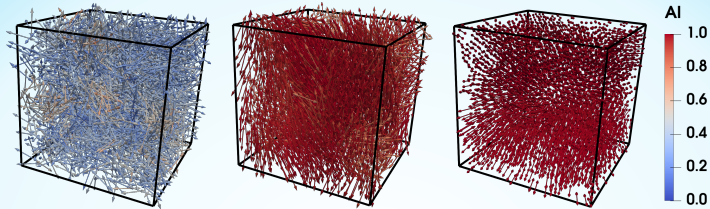


- Mechanical interactions

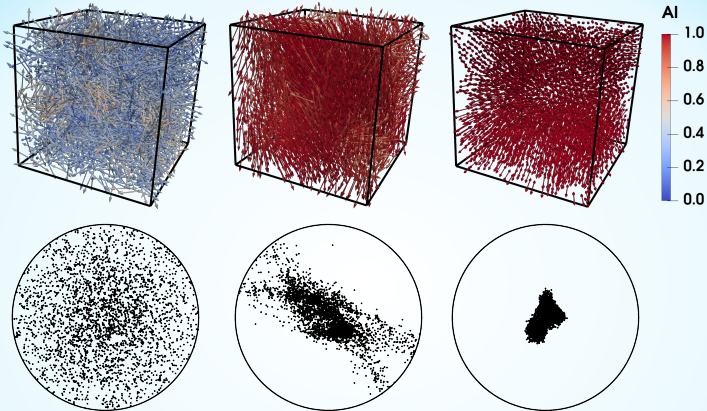




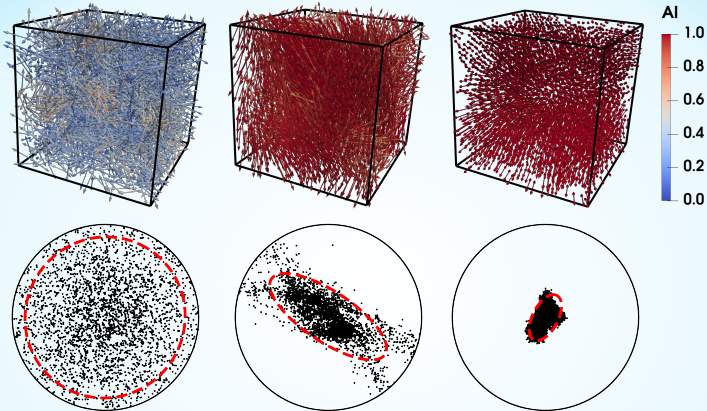
P. Chassonnery, J. Paupert, A. Lorsignol, C. Sév rac, M. Ousset, P. Degond, L. Casteilla and D. Peurichard. "Fiber crosslinking drives the emergence of order in a three-dimensional dynamical network model". Royal Society Open Science, 11:231456, Jan 2024.



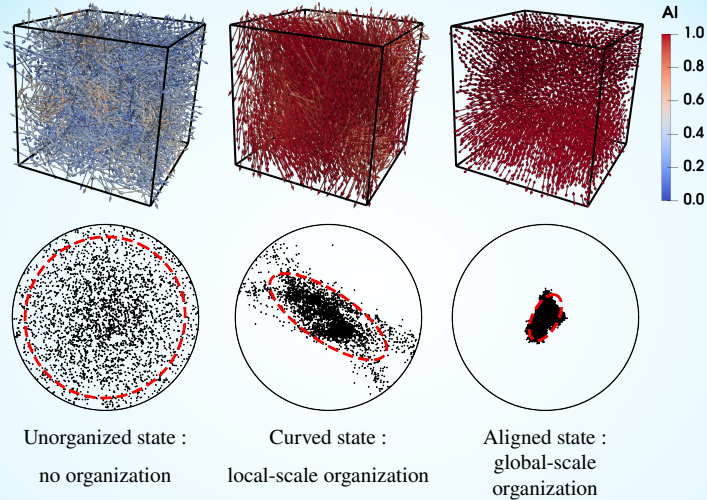
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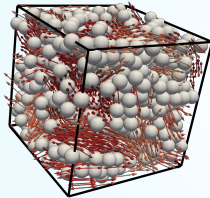
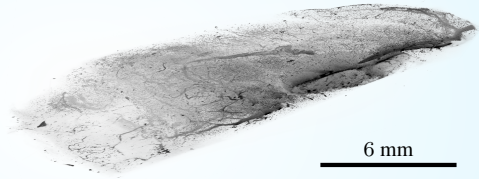
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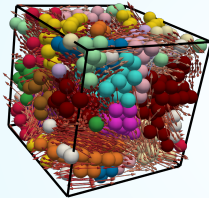
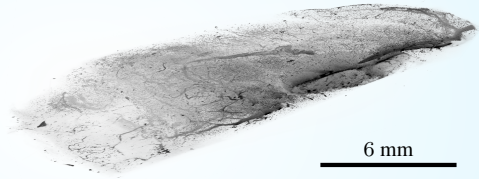
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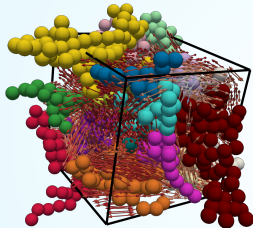
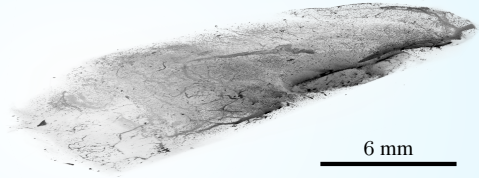
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In silico segmentation*In vivo* segmentation

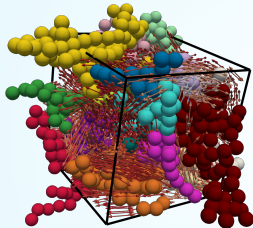
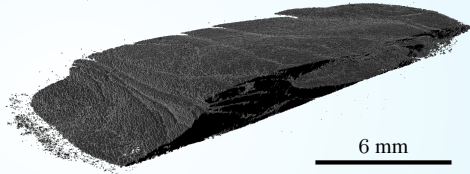
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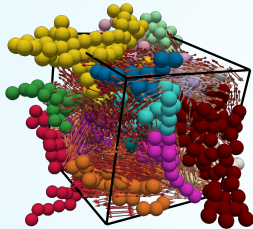
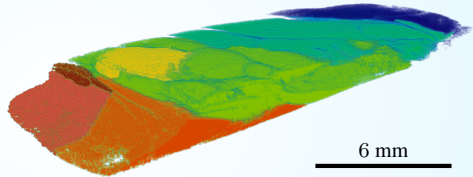
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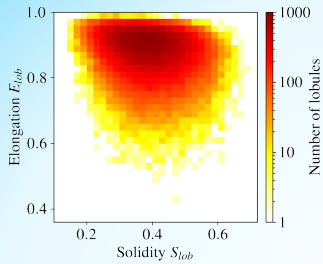
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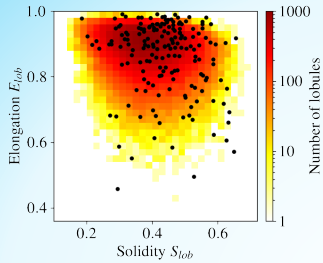
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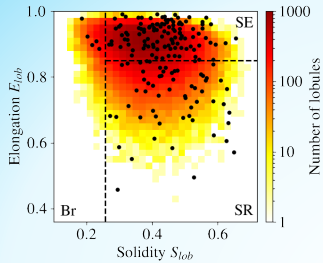
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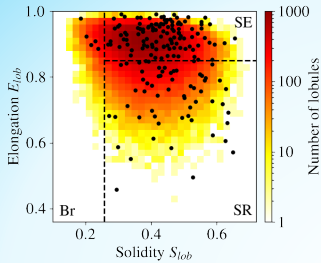
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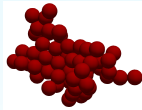




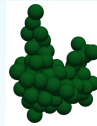




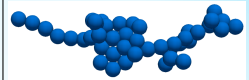
Solid elongated

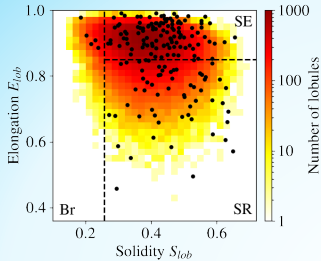


Solid rounded

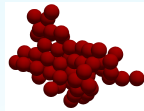


Branching

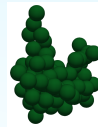




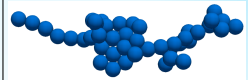
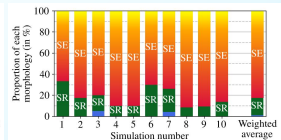
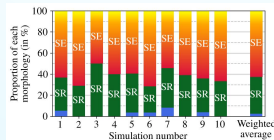
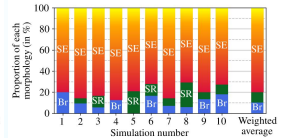
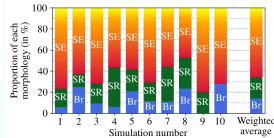
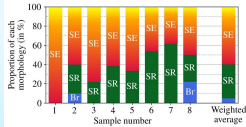
Solid elongated



Solid rounded



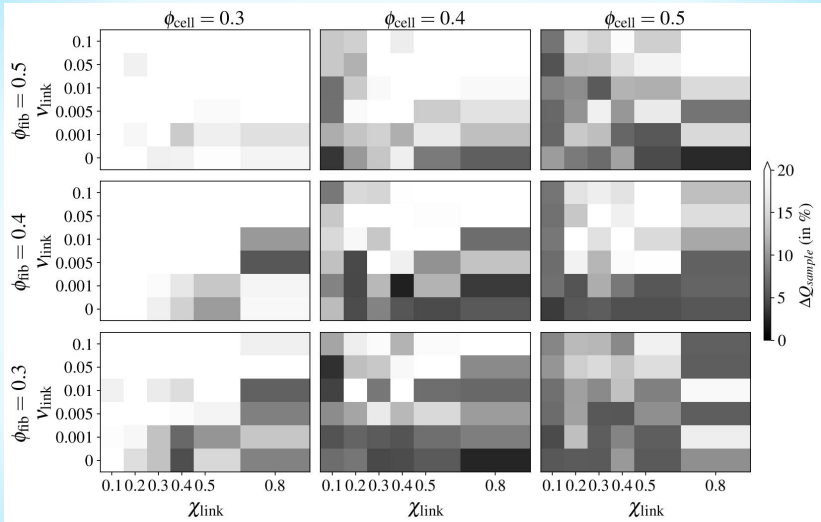
Branching

*In silico* distribution for various parameters*In vivo* distribution

$$\Delta Q_{sample}(P) = \sqrt{(N_{SE}^{vivo} - N_{SE}(P))^2 + (N_{SR}^{vivo} + N_{SR}(P))^2 + (N_{Br}^{vivo} - N_{Br}(P))^2}$$

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- ★ Classification in three morphological types : branching, solid rounded and solid elongated.
- ★ Similar repartition of these morphologies *in vivo* and *in silico*.
- ★ The morphology of *in silico* lobules is mainly driven by the ECM characteristics.
 - 2D mathematical model (Peurichard et al, 2016).
 - *In vitro* experiments on organoids (Escudero et al, 2023).
 - *In vivo* experiments on tissue reconstruction after injury (Pacary et al, 2024).