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CLOGGING OF A MODEL PORE BY A YEAST SUSPENSION (*SACCHAROMYCES CEREVISIAE*)

T erence Desclaux^{a,b}, Paul Duru^a, Pierre Joseph^b, Morgan Delarue^b, Olivier Liot^a



Introduction

The capture of solid particles in a porous medium is essential in many fields such as liquid chromatography, or infiltration of groundwater¹. However, these processes have a major drawback: the porous media can get fouled and eventually clogged. **The amount of accumulated solid matter can get so high that it forms a cake that blocks the flow of fluid and matter.** Fundamentally, clogging is based on various processes, that occupy a wide variety of spatio-temporal scales. In the past, it has been extensively studied at the macroscopic scale, but **information at the pore scale has remained inaccessible until the use of microfluidic devices**².

Today, the clogging of a pore by rigid and inert particles is well documented³, and the use of deformable particles is starting to be reported⁴. **But the study of bio-clogging - clogging with biological objects - opens many topical research questions:** living cells have particular properties that can impact both the clogging scenario and the properties of the resulting clog. They are **deformable, anisotropic objects endowed with**

adhesion mechanisms and behaviors specific to the living world (division, respiration, death).

A well-reported consequence of these particular properties is that the cake is **compressible**⁵: **its volume changes with hydro-mechanical constraints.** At the microscopic scale, it is believed that this is a result of **particle deformation and/or particle rearrangements, but this could not be directly observed in filtration systems.**

Moreover, that compressibility is reported to be **reversible**⁶: at the macroscale, the hydraulic resistance of the cake, at a given pressure, is independent of whether the cake has been exposed previously to higher pressures. **At present, there is no explanation for the essentially reversible nature of microbial cake compression.**

The object of this work is therefore the study of the clogging of a model pore by biological particles with well-controlled properties: the baker's yeasts, *Saccharomyces cerevisiae*, in particular with regard to cake compressibility.

Experimental protocol

1/ Yeast suspension

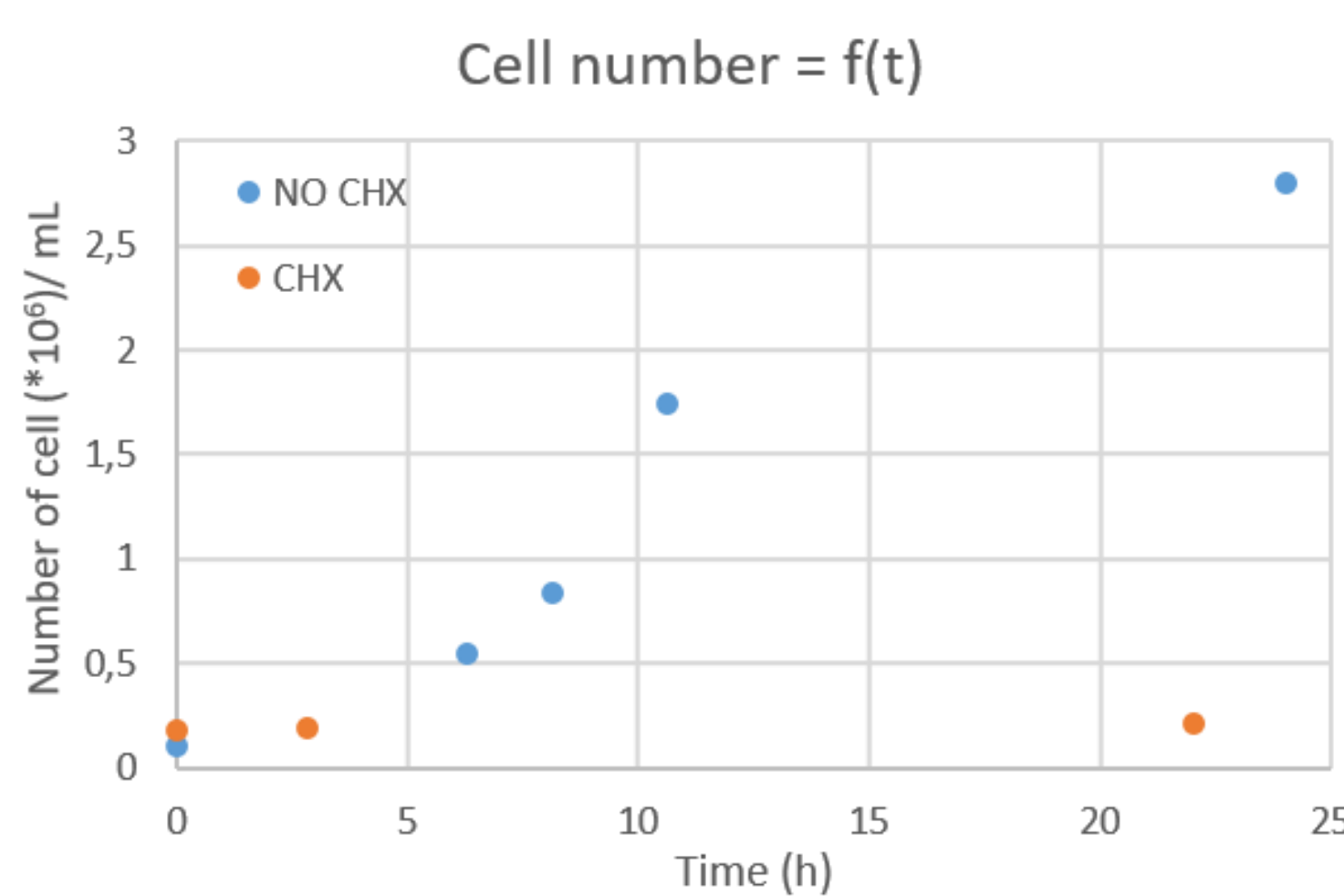
- Culture in Synthetic Complete Dextrose (SCD) Broth, mixed with iodixanol solution.
- > Medium density = Cellular density
- Exponential phase of growth
- 10⁵ cell / mL

Cycloheximide (CHX)

-> Antibiotic: stop protein synthesis

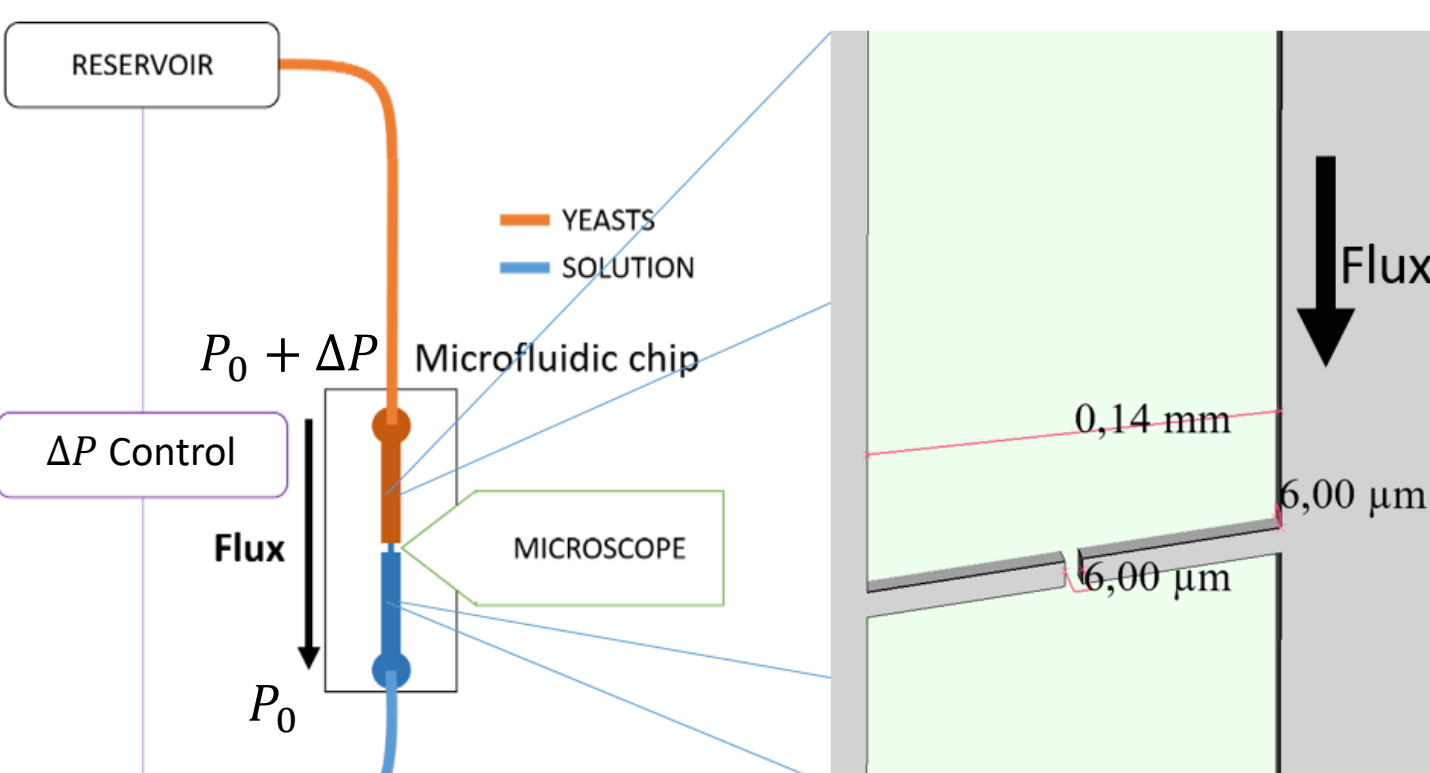
PROLIF Without CHX

NO PROLIF With CHX



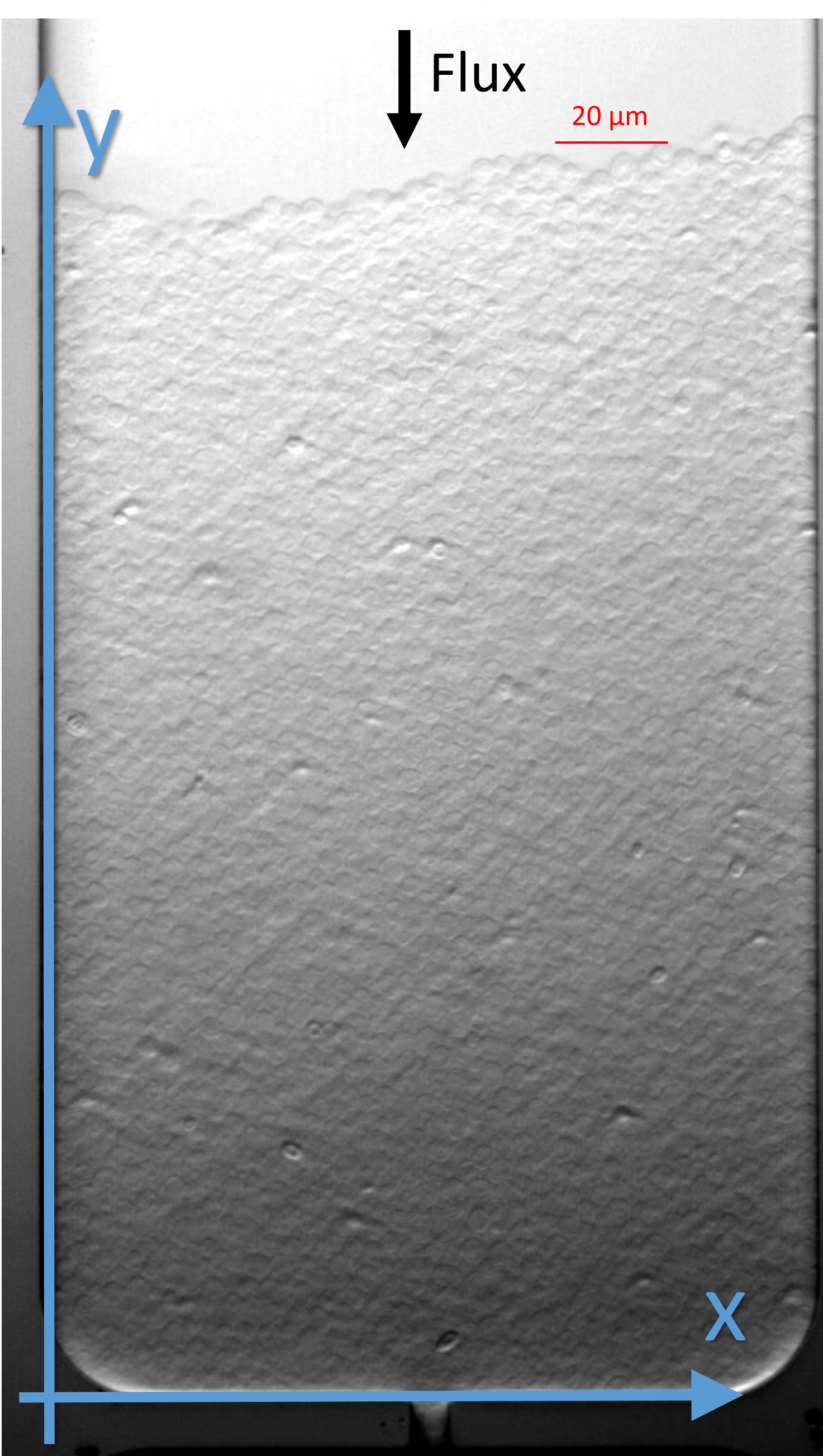
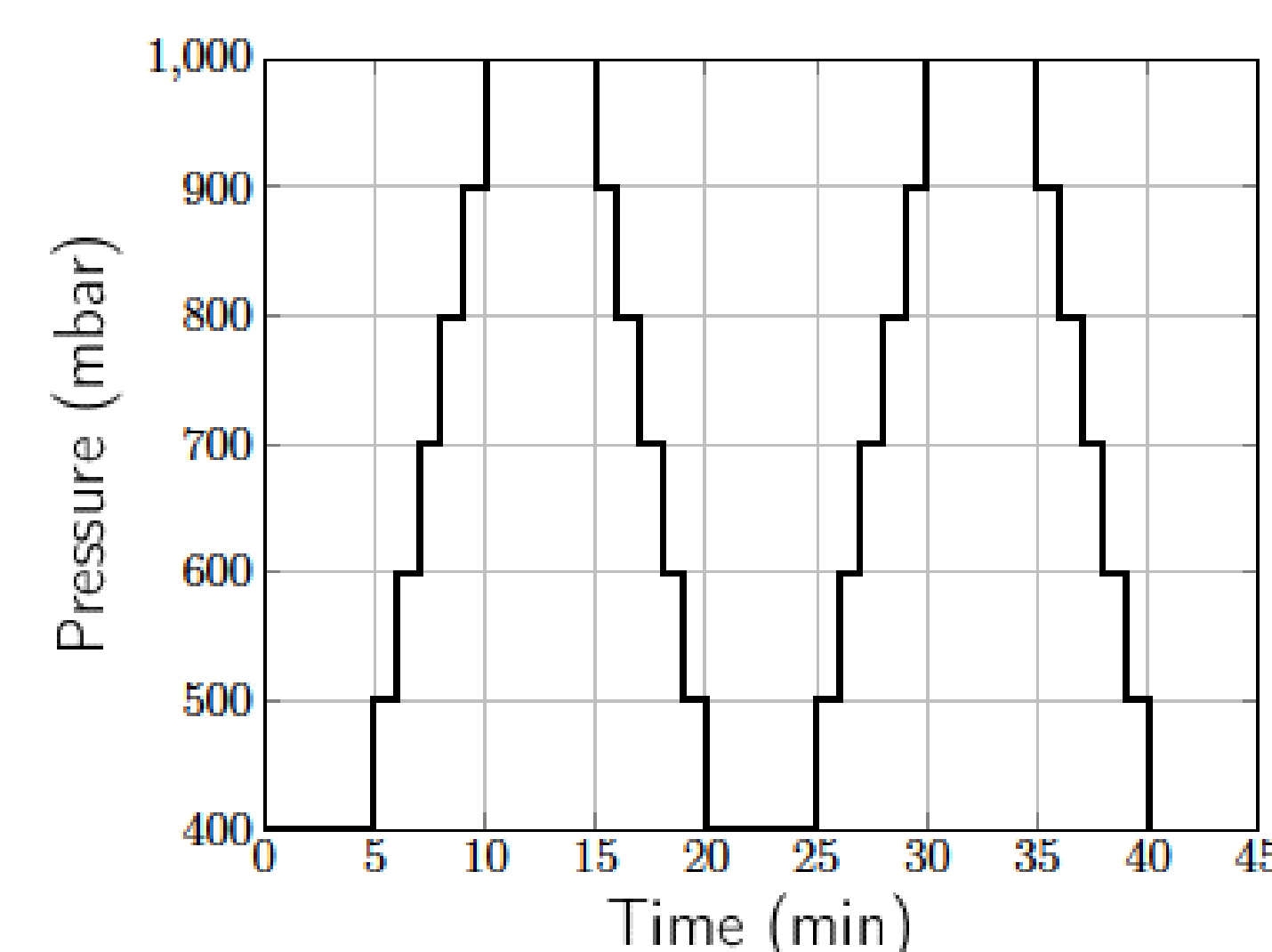
2/ Cake growth

- Suspension pushed through silicon-glass micro-model
- ΔP = 400 mbar during 1 hour



3/ Compression/Decompression cycles

- ΔP ∈ [400 mbar ; 1000 bar]
- Step size = 100 mbar.min⁻¹



Movie

Flash the QR Code -> (Accelerated 100x)

Cake compression/decompression

Analysis of collective displacements and local rearrangements

1/ Select 2 images

2/ Pretreat and grid them

3/ Compute an optimal affine transformation to join images -> **Collective displacements (δ)**

4/ Quantify the non affine component (squared difference) -> **Local rearrangements**

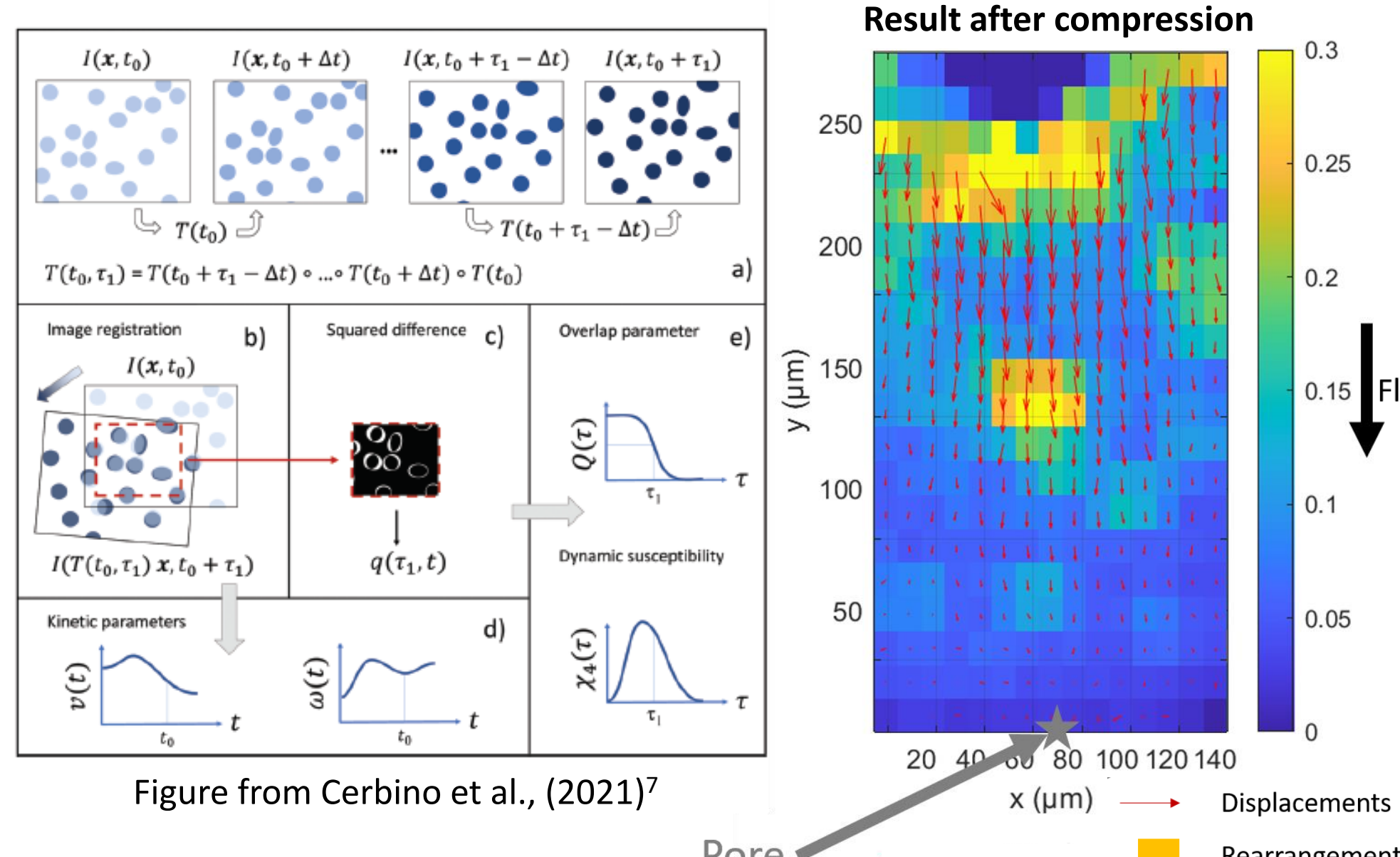


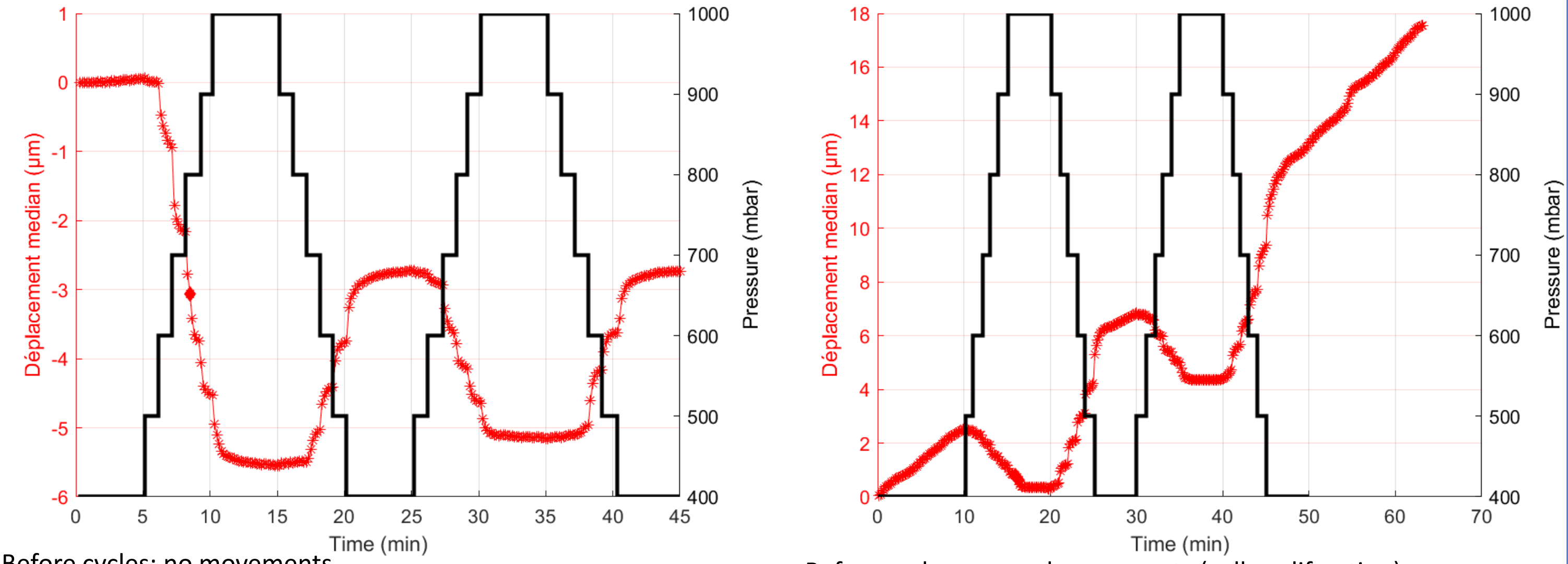
Figure from Cerbino et al., (2021)?

Results

NO PROLIF

PROLIF

Displacement dynamics at y = 100 μm

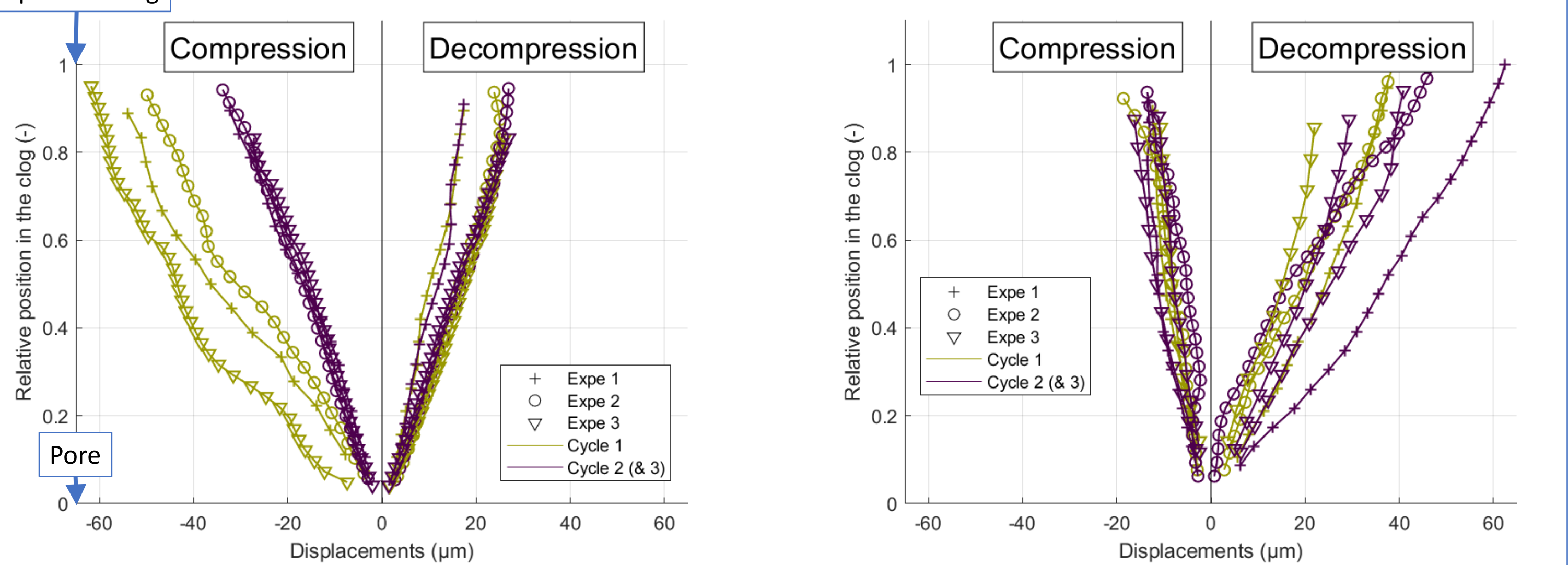


> Before cycles: no movements.

> Final state: smaller clog than initial state

> Before cycles: upward movements (cell proliferation)

Displacement profiles



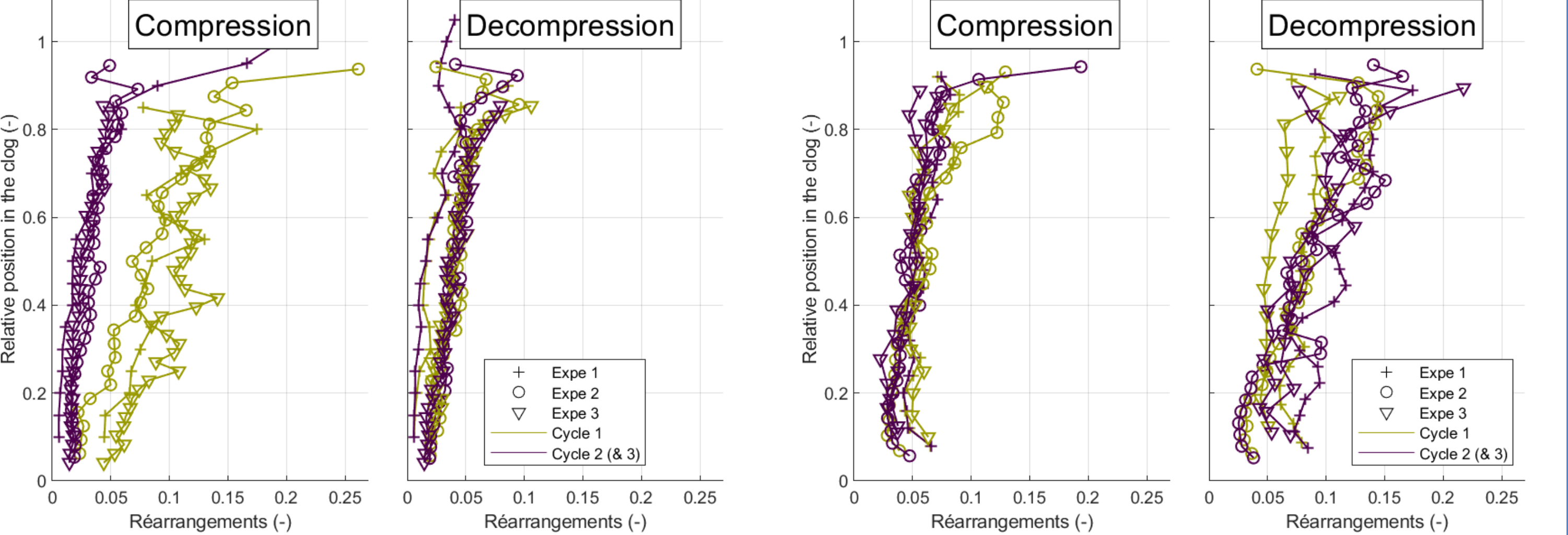
> Displacements are the larger at first compression

> 2nd cycle : δ_{compression} = - δ_{decompression}

> 1st cycle = 2nd cycle

> δ_{decompression} > δ_{compression}

Rearrangements profiles

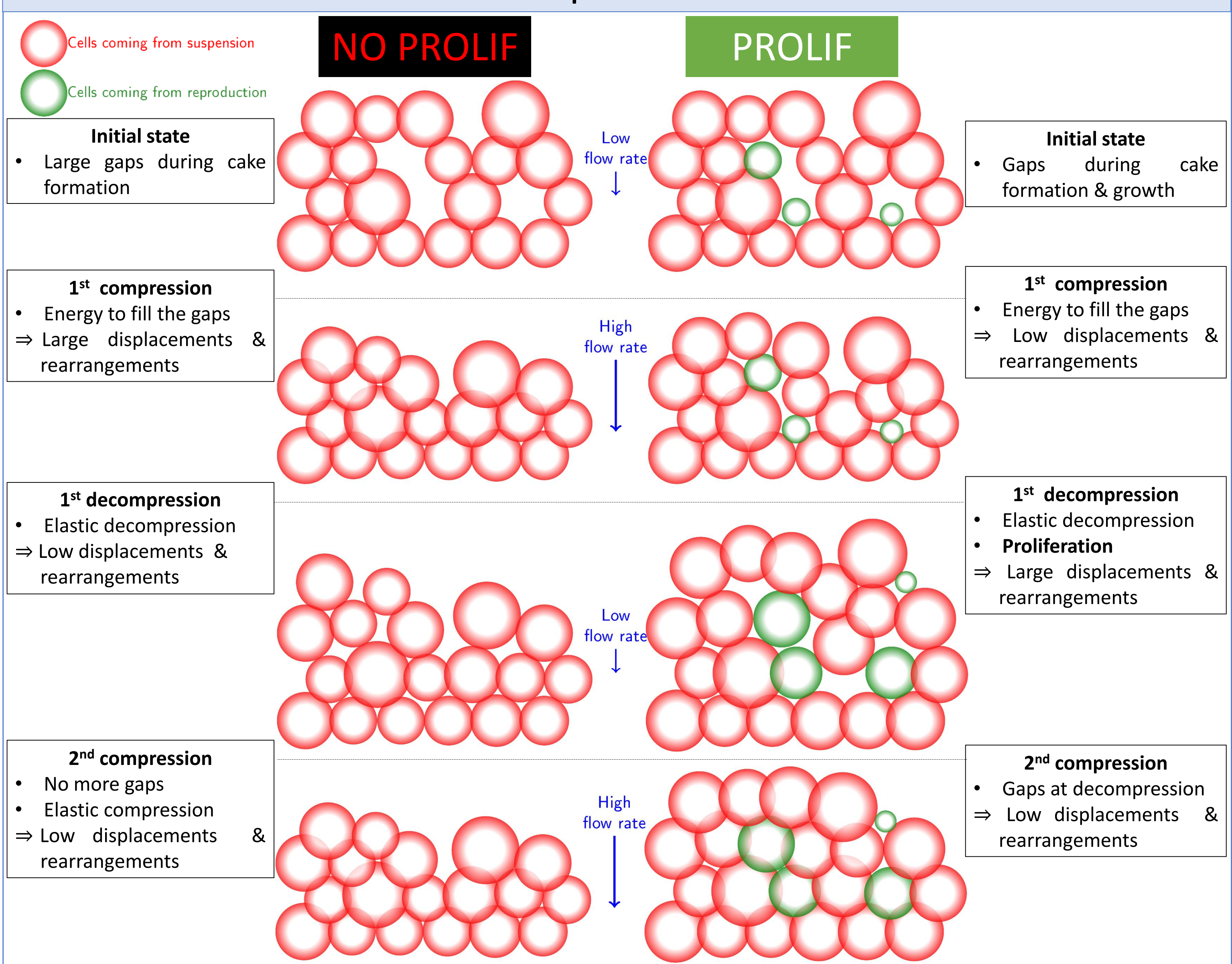


> Large rearrangements at 1st compression, no rearrangements after.

> Same rearrangements at 1st or 2nd compression

> Rather large rearrangements at decompression

Interpretations



Conclusions

Using microscopic observations of the cake during filtration, we were able to measure both collective displacements and local rearrangements that happen during cake compression. With the help of CHX, we were able to stop protein synthesis, in order to disentangle what could be explained by physical properties of cells and structural properties of the clog or by division and growth. When proliferation is stopped, the cake behaves like an aggregate of hydrogel beads, with a large and irreversible first compression, followed by elastic movements, with no rearrangements. When cells proliferate, large displacements and rearrangements are measured at decompression. Besides, successive compression/decompression cycles exhibit the same displacements and rearrangements: the compression is fully reversible. These results suggest that cellular proliferation and clog mechanical and structural properties play a major role in cake compression reversibility.



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