université de BORDEAUX

UMR5798
Laboratoire Ondes et Matière d'Aquitaine

Master 2 Internship

Title: Probing the growth mechanisms of living cells : from single cell experiments to population behaviour.

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PhD funding (if any): proposals are presently submitted for this funding

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Project:

As the elementary building block of living systems, cells are active mechanical machines that, in contrast to amorphous materials, have the fascinating property to constantly remodel their structural organization to withstand forces and deformations and to adapt to their mechanical environment [1,2]. The mechanobiology of living cells and tissues is nowadays considered as an important actor in the maintenance and restauration of their normal functions after stress and in their intra- and inter- tissular cross-talk. Living cells and tissues can adopt a variety of mechanical behaviors, from strictly periodic to apparently stochastic and scale invariant dynamics which are dictated by both internal and external constraints.

Our recent experimental developments on single cells have enlightened that living cells are not simple visco-elastic systems but that they instead respond to stress with a continuous range of relaxation times [3,4]. Living systems are fundamentally out-of-equilibrium materials that include a high fraction of defects (compared to nonliving materials) which give them an impressive ability to dissipate a mechanical energy over a wide range of frequencies. The presence of these local mechanical singularities have been suspected with AFM indentation experiments, in which localized avalanches of fractures of the cell cytoskeleton have be observed [5].

This property is embodied in power-law behaviors of the mechanical parameters, meaning in particular that their temporal behavior never converges to a stationary limit ($t \rightarrow \infty$), contrarily to exponential decay functions encountered in traditional viscoelastic systems. We have proposed a wavelet-based decomposition of these signals [3,4], and tested our methodology on atomic force microscopy (AFM) indentation experiments on single living cells in both healthy and pathologic situations (from hematopoietic cells [5] and muscle cells [4,6]). More recently compression microsystems have also been designed with partner teams in Lyon, to study the impact of permanent stress on the growth and proliferation of cells [7].

The present internship aims at combining single cell indentation using AFM with whole population compression experiments. In both cases the stress will be monitored locally or globally and the induced strain will be followed in real time thanks to the coupling of the mechanical systems with a quantitative phase microscope (QPM). The intership student will perform AFM and QPM experiments and he will work in close concertation with E. Harté from the Optics and Instrumentation Ingeniering Team of the LOMA to design a version of the compression system [7] that will be coupled to a QPM microscope. The nonlinear reponse (plasticity and/or fracture) of cells to stress will be focused on, combining experiments and analytical tools that we have developed during the past few years [8,9,10]. The key question adressed during the intership will be to find out if the nature of these avalanches of local ruptures may lead to a global destruction of the cells, and in this case which type of statistical distribution of fracture sizes they adopt. Compared to non-living vitrous systems which have also been shown to behave with avalanches of fractures, we will search for local and global evidences for membrane repair mechanisms which are been suggested by cell biologists [11].

References:

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