Research Networking Programmes

Short Visit Grant or Exchange Visit Grant

(please tick the relevant box)

Scientific Report

Scientific report (one single document in WORD or PDF file) should be submitted online within one month of the event. It should not exceed eight A4 pages.

Proposal Title: Mechanical stress induced by cell division favors tissue's anisotropy

Application Reference N°: 4441

1) Purpose of the visit

The main objective of the visit was to continue an enriching bidirectional collaboration in the field of biophysics between the group of Prof. J. F. Joanny at the Institute Curie and the group of J. Casademunt at the Universitat de Barcelona, whose results would be relevant for a broad audience in life science.

The Phd. student C. Blanch-Mercader started a work on a theoretical description of tissue growth, when he visited the group of Prof. J. F. Joanny in 2012. This work was completed satisfactorily during the current stay that has been financially supported by ESF Research Networking Programme QuanTissue.

2) Description of the work carried out during the visit

The short visit lasted from October 2013 to January 2014. The work carried out during the visit could be subdivided in two main blocks:

- The first month was devoted to the development of a manuscript that summarizes the main results obtained in the project of tissue mechanics explained below.

- The rest of the short stay was devoted to construct a physical model to address recent experimental observations in the mechanical responses of cancer cell aggregates by members of the Institute Curie, [1-3]. The progresses are not conclusive so far.

[1] F. Montel, M. Delarue, J. Elgeti, L. Malaquin, M. Basan, T. Risler, B. Cabane, D. Vignjevic, J. Prost, G. Cappello, J.-F. Joanny, Phys. Rev. Lett. 107(18), 188102, (2011).

[2] F. Montel, M. Delarue, J. Elgeti, D. Vignjevic, G. Cappello, J. Prost, New J. Phys. 14, 055008, (2012)

[3] M. Delarue, F. Montel, O. Caen, J. Elgeti, J. M. Siaugue, D. Vignjevic, J. Prost, J.-F. Joanny, G. Cappello, Phys. Rev. Lett. 110, 138103, (2013).

3) Description of the main results obtained

The regulation of the growth and shape of tissues is a fundamental property of living organisms. Recently developed experimental techniques permit to address the role of forces in morphogenesis. For example, the local forces produced by cell division events, may induce a fluidization of the tissue at longer time scales than the cell cycle. On the contrary, the properties of the cells that compose a tissue can be affected by the mechanical state of the tissue itself. Therefore, it becomes of interest the study of the mechanisms by which growing tissues attain specific morphologies, [1,2].

In particular, we have focused on the study of the expected shapes of a polarized tissue due to anisotropic cell division. This mechanism requires two essential ingredients: cell replication coupled to a global polarization, [3]. In general, the forces produced by this mechanism are anisotropically distributed. A reference system, in which we expect that this mechanism may be relevant, is the wing disk of Drosophila melanogaster, which during embryogenesis changes its shape from an initial disk (isotropic) of ten microns of diameter into an elliptical shape (anisotropic) of a hundred microns in length at the pupal stage, [4].

We have formulated a physical model to describe the temporal evolution of a 2d tissue, in which the rate and the axis of cell division are thought to be homogenous, subjected to three different passive forces: viscous stresses, friction with a substrate and capillary forces.

The model belongs to the family of free-boundary problems, and so we have used conformal mapping techniques to study the morphodynamics of an initially circular tissue numerically. As discussed in Ref. [1], anisotropic cell division induces elongated shapes. In general, we have observed that at the first time steps a circular tissue deforms into an ellipse. However at sufficiently long times, the friction forces prevail over the effects of the rest of the forces on the morphodynamics (including the forces generated by cell division), and as a consequence the tissue tends to a disk. The crossover is controlled by a single characteristic length scale, which arises from the comparison between viscous and friction forces. Therefore, one of the key results of this work is that the aspect ratio shows a maximum at finite time. Finally, we have derived scaling laws for the maximal aspect ratio of the tissue in the various time regimes, which depend on the physical properties of the tissue.

[1] T. Lecuit, L. Le Goff, Nature 450, 189 (2007).

[2] F. Corson, O. Hamant, S. Bohn, J. Traas, A. Boudaoud, Y. Couder, Proc. Natl. Acad. Sci. U.S.A. 106, 8453 (2009)

[3] J. Ranft, M. Basan, J. Elgeti, J. F. Joanny, J. Prost, F., Jülicher, Proc. Natl. Acad. Sci. U.S.A. 107, 20863 (2010).

[4] T. Bittig, O. Wartlick, M. González-Gaitán, F. Jülicher, Eur. Phys. J. E 30, 93 (2009).

4) Future collaboration with host institution (if applicable)

J. Casademunt's group has been collaborating with the host institution for about 10 years, and so it is probable to be future collaborations between both groups.
At the end of 2014, C. Blanch-Mercader will defend his thesis and so there are no short visits planned for this year.
During the current visit, we started an original project on the mechanical response of cancer cell aggregates.
This visit might serve as a basis to initiate new collaborations in tissue mechanics and developmental biology, which importantly they may help new Phd. students.

5) Projected publications / articles resulting or to result from the grant *(ESF must be acknowledged in publications resulting from the grantee's work in relation with the grant)*

For the moment this short stay have helped to produce one scientific article:

- C. Blanch-Mercader, J. Casademunt, and J. F. Joanny, *Morphological dynamics of growing polarized tissues*, (2014) (in progress)

6) Other comments (if any)

C. Blanch-Mercader has participated in the workshop " *Mechanics and growth of tissues: From Development to Cancer* " held the 13-16 of January of 2014. He has presented the next poster

Title: Anisotropic growth of tissues

Authors: C. Blanch-Mercader, J. Casademunt and J.-F. Joanny

Abstract:

We study and classify the morphologies expected during tissue growth in two-dimensions on a substrate using a hydrodynamic coarse grained description. Cell division contributes to cell rearrangements and induces at long time scale a fluidization of the tissue. We focus on the deformations caused by anisotropic cell division. We make use of conformal mapping techniques, broadly used in free-boundary problems, to complement the analytical calculations performed for small deformations around a circular shape. Starting from a circular tissue, we find that the anisotropy of the tissue increases and has a maximum value at a finite time; at very long times, friction forces prevail and induce eventually isotropic shapes. We also derive scaling laws for the anisotropy of the tissue in the various time regimes.