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Cell biology and soft matter physics both share similar orders of magnitude with two important differences: biological systems are clearly out of equilibrium and molecular specificity can be strongly relevant. We are using the standard tools of soft matter physics to provide a quantitative description of cellular systems, and with this analysis of biological systems, we are raising an interesting number of new and challenging physical questions. In collaboration with biologists, we mainly concentrate our efforts on understanding some of the physical features of cell morphology and dynamics and of the mechanics and growth of tissues.

Cells contain a large number of components, but if we focus on mechanical properties, only a few classes of these components are relevant, e.g. the cytoskeletal network, molecular motors, phospholipid membranes and a large class of adhesion molecules such as integrins or cadherins. We therefore study each of these components, keeping in mind the importance of the non-equilibrium behavior. In some cases, this requires the introduction of new physical concepts such as “active” membranes, “active” gels or “isothermal ratchet”, a model used to describe molecular motors by the Brownian motion of a particle switching between two different states.

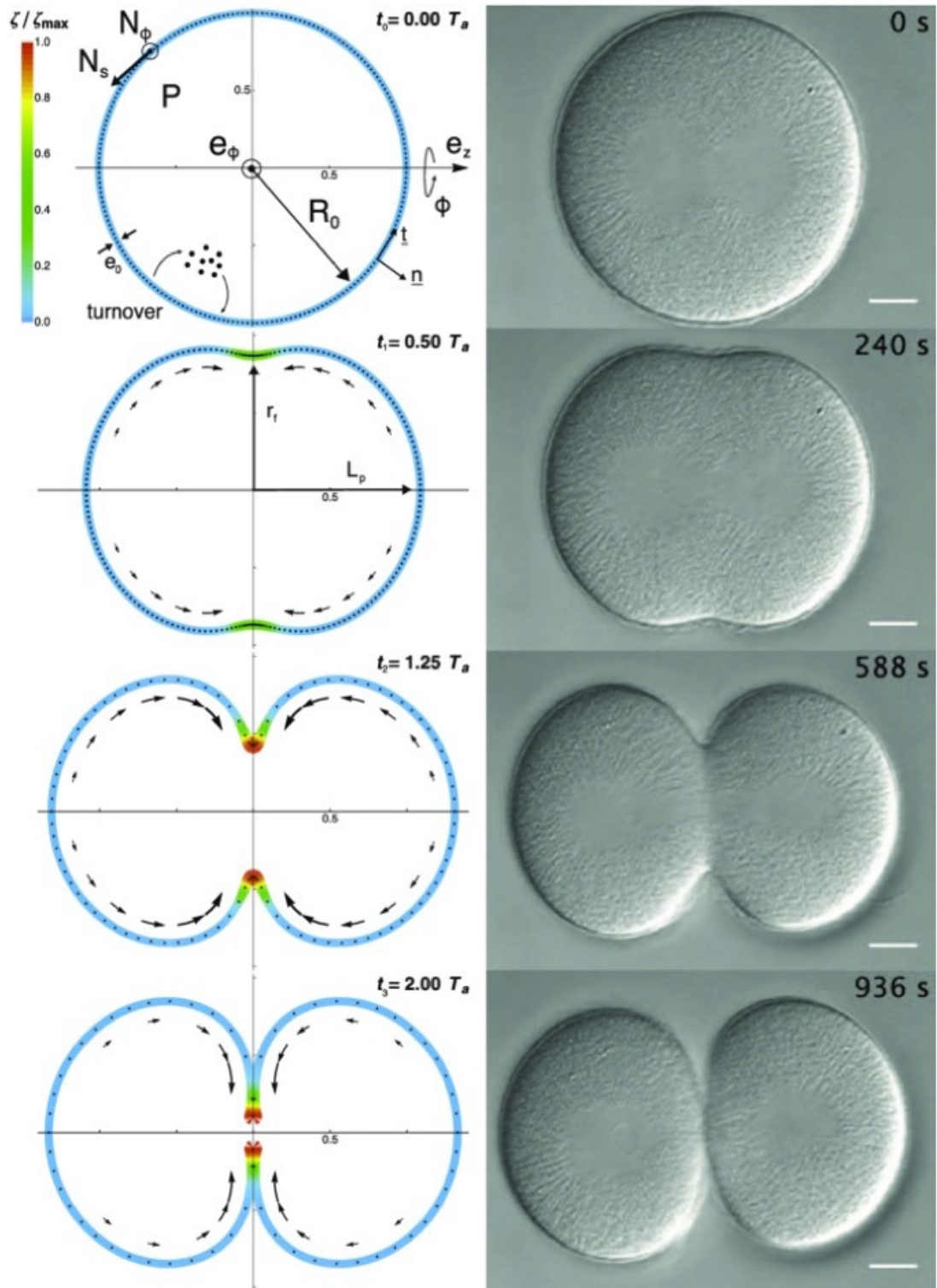
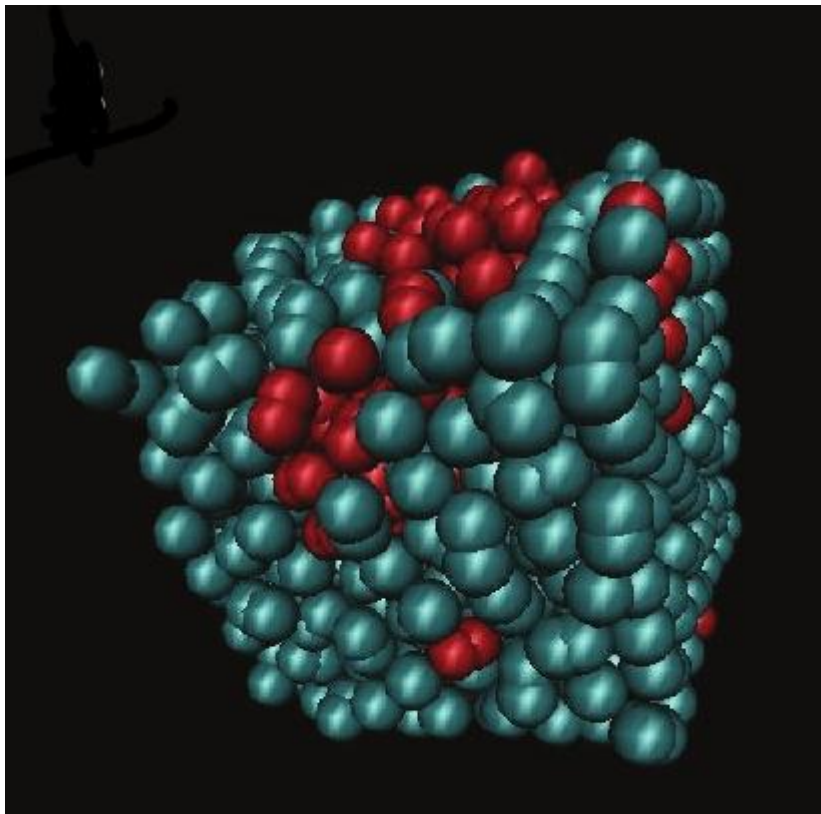


Figure 1 : Calculated shape of a dividing cell during cytokinesis and comparison with the shape of a Sand Dollar egg. (courtesy G. Von Dassow)

To optimise our physical understanding, we systematically carry out quantitative comparison between theoretical and experimental data obtained by varying controlled parameters. For instance, we are contributing to the theoretical description of the actin cortex and its role during cell division and cytokinesis. We are also trying to understand what fixes the volume of a cell. As an example we show on Fig.1 the results of calculations of the shape of a sand dollar egg during cytokinesis.



Competition between tissues: Numerical simulations of the competition between two different tissues.

We have now reached a reasonable physical understanding of single components and are consequently extending our analysis to the collective behavior of many components. We can already describe certain aspects of cell behavior such as phospholipidic nanotube pulling by molecular motors, cell motility, cell division and mechano-transduction. A large part of our work is now devoted to the effect of mechanical stresses on the growth of tissues. We have for example performed numerical simulations of tissues competing for space (Fig. 2).

We also keep close contact with the evolution of statistical physics. In particular we have derived a general relation between the linear response of a system to any external perturbation and its fluctuations. We have tested this relation on the mechanical properties of the hair bundle of ear cells. .

Key publications

Year of publication 2018

Vincent Nier, Grégoire Peyret, Joseph d'Alessandro, Shuji Ishihara, Benoit Ladoux, Philippe Marcq (2018 Oct 11)

Kalman Inversion Stress Microscopy.

Biophysical journal : [DOI : S0006-3495\(18\)31065-8](https://doi.org/10.1038/s0006-3495(18)31065-8)

Duclos G., Blanch-Mercader C., Yashunsky V., Salbreux G., Joanny J.-F., Prost J., Silberzan P. (2018 Oct 3)

Spontaneous shear flow in confined cellular nematics

Nature Physics : [DOI : 10.1038/s41567-018-0099-7](https://doi.org/10.1038/s41567-018-0099-7)

Year of publication 2017

Francesco Gianoli, Thomas Risler, Andrei S. Kozlov (2017 Dec 19)

Lipid bilayer mediates ion-channel cooperativity in a model of hair-cell mechanotransduction

Proceedings of the National Academy of Sciences of the United States of America : 114 : E11010-E11019 : [DOI : 10.1073/pnas.1713135114](https://doi.org/10.1073/pnas.1713135114)

Thuan Beng Saw, Amin Doostmohammadi, Vincent Nier, Leyla Kocgozlu, Sumesh Thampi, Yusuke Toyama, Philippe Marcq, Chwee Teck Lim, Julia M Yeomans, Benoit Ladoux (2017 Apr 14)

Topological defects in epithelia govern cell death and extrusion.

Nature : 212-216 : [DOI : 10.1038/nature21718](https://doi.org/10.1038/nature21718)

Duclos G., Erlenkämper C., Joanny J.-F., Silberzan P. (2016 Sep 12)

Topological defects in confined populations of spindle-shaped cells

Nature Physics : 13 : 58-62 : [DOI : 10.1038/nphys3876](https://doi.org/10.1038/nphys3876)

Year of publication 2016

Vincent Nier, Shreyansh Jain, Chwee Teck Lim, Shuji Ishihara, Benoit Ladoux, Philippe Marcq (2016 Apr 14)

Inference of Internal Stress in a Cell Monolayer.

Biophysical journal : 1625-35 : [DOI : 10.1016/j.bpj.2016.03.002](https://doi.org/10.1016/j.bpj.2016.03.002)